Expression of Interest

Directorate of Geology & Mining Uttarakhand is an Uttarakhand state Government organization responsible for administrate the Mining activities in state. As on date, 223 insitu based mining leases are sanctioned by the government for extraction of Soapstone, Magnesite, Limestone and Silica sand minerals. These mines are located in districts Bageshwar, Pithoragarh, Chamoli, Tehri Garhwal, Almora and Uttarkashi.

Directorate of Geology & Mining Uttarakhand Dehradun is inviting applications from reputed private companies, fulfilling following criteria for empanelment as service agency to carry out slope stability analysis of the existing mining lease areas and also for the new mining areas.

1. **Brief Introduction of the geo-tectonic and seismicity:** Uttarakhand state has two important geo-tectonic divisions: the Himalayan belt and the Indo-Gangetic plains (IGP). These two divisions are demarcated by the Himalayan Frontal Thrust (HFT), tectonic boundary separating Himalayan wedge from the plains. The districts Haridwar, Udam Singh Nagar and Haldwani area of Nainital district predominately falls in the frontal Himalaya under Indo-Gangetic division. Remaining districts of Uttarakhand are located within Himalaya belt. Himalaya region is geotectonically a complex zone having seismic activity due to the collision of the India and Eurasia tectonic plates. Further the Himalayan mountain belt is sub-divided into four geotecotnic units with division parallel to the Himalayan arc. Adjacent to the IGP to the north HFT, Siwalik Himalaya has sedimentary and meta-sedimentary rocks of younger Himalayan geological rock formations. Siwalik Himalaya is separated from Lesser Himalaya to its north by the Main Boundary Thrust (MBT) which is seismically more complex. Further north, the Higher Himalayan rocks are divided from Lesser Himalaya by Main Central Thrust (MCT) and to its north Tethys Himalaya exists which is demarked by South Tibetan Detachment (STD).Geologically, the complexity in tectonics and geological rock age increases towards the higher Himalaya. Also, the mineral prospects (in-situ minerals) of different types are proportionally more towards high Himalayan Mountains.

   Districts near the MCT mainly Pithoragarh, Chamoli, Uttarkashi and Rudarprayag are within high tectonic stress concerning seismic stability. In-contrast, districts like Dehradun, Tehri, Pauri, Almora and Bageshwer experience relatively less tectonic stress and low seismic activity. Therefore monitoring of seismicity to micro-earthquake level is important aspect concerning to seismic stability to the mines.

To conduct a comprehensive slope stability assessment of open-pit mines located in hilly and mountainous terrain, particularly in geologically sensitive and seismically active regions. The goal is to ensure the long-term stability of mine slopes and waste dumps, safeguarding human life, equipment, and the environment while maintaining operational and economic viability.

2. Mining Activities in Uttarakhand:

Mining activities being carried out in Uttarakhand, there are two types of mining in the state: (1) River bed mining and (2) In-situ Open Cast mining for minerals soapstone, Magnesite, Limestone and Silica sand.

The state Government has granted leases for insitu rock based mining in various districts, with the following details:

Sr. No.	Name of district	Number of issued mines	Minerals for which Mines are issued
1	Bageshwar	171	Soapstone, Magnesite
2	Pithoragarh	33	Soapstone, Magnesite
3	Chamoli	13	Soapstone
4	Tehri Garhwal	4	Limestone
5	Uttarkashi	1	Silica sand
6	Almora	1	Soapstone

These mines are executed as open-cast mining. The depth of the mining is not restricted and it may go up to the depth, where the minerals can be found.

3. Scope of Investigation

A multidisciplinary approach will be adopted, encompassing geological, geotechnical, and geophysical studies to evaluate rock mass conditions, subsurface characteristics, and potential failure mechanisms.

A. Geological Investigation

- Desktop study and literature review
- Field geological mapping
- Rock mass classification
- Photogrammetry and remote sensing analysis

B. Geotechnical Investigation

- Drilling and core logging
- Laboratory testing of rock samples
- Rock discontinuity and structural surveys

C. Geophysical Investigation

- Seismic reflection profiling
- Electrical Resistivity Tomography (ERT)
- Multichannel Analysis of Surface Waves (MASW)

D. Data Handling and Analysis

- Field data acquisition
- Data processing and interpretation
- Integration of multidisciplinary datasets
- Development of slope stability models

E. Stabilization and Risk Mitigation Measures

Based on the findings, appropriate stabilization strategies will be implemented.

4. **Detailed Scope of Work for Slope Stability Analysis by Empanelled Private Consultants**:

The empanelled private consultants shall undertake a comprehensive Slope Stability Analysis (SSA) for individual mining lease areas, focusing on open-cast mines in seismically active and geologically complex Himalayan terrains. The scope integrates a multidisciplinary approach, incorporating advanced and innovative technologies to ensure accurate assessment, risk mitigation, and sustainable mining practices. The work shall cover existing and new mining leases in districts such as Bageshwar, Pithoragarh, Chamoli, Tehri Garhwal, Almora and Uttarkashi, with representative sections analyzed at least every 50 meters along slopes

Key components of the scope include:

A. Geological Investigation

- Conduct desktop studies, literature reviews, and historical data analysis on regional tectonics, seismicity, and past slope failures.
- Perform detailed field geological mapping, including identification of faults, lithological units, and groundwater behaviour.
- Classify rock mass using standard systems like RMR (Rock Mass Rating) or Q-system, supported by conventional surveying for terrain and discontinuity analysis
- Utilize basic remote sensing (e.g., satellite imagery from free sources like Sentinel or Landsat) and simple GIS-based terrain modelling for preliminary risk zoning and slope morphology analysis

B. Geotechnical Investigation

- Execute borehole drilling (up to required depths for mineral extraction) and core logging to assess rock/soil properties.
- Conduct laboratory testing on core samples such as Uniaxial Compressive Strength (UCS), tri axial test, point load tests, tensile strength and direct shear tests, density, specific gravity, porosity etc in collaboration with NABL-accredited labs or institutions like IITs/NITs.
- Perform rock discontinuity surveys and structural analysis, incorporating hydrological data (e.g., permeability, pore pressure) to model water-induced instabilities.

C. Geophysical Investigation

- Deploy essential non-invasive methods like Electrical Resistivity Tomography (ERT) and Multichannel Analysis of Surface Waves (MASW) to delineate subsurface features and groundwater tables

D. Data Handling, Analysis, and Modelling

- Acquire and process field data using basic GIS software (e.g., ArcGIS or open-source alternatives) and integrate datasets into 2D models. ·
- Develop slope stability models using standard numerical methods: Limit Equilibrium Method (LEM) via tools like RocScience Slide2; basic Finite Element Method (FEM) via RS2 for 2D analysis. ·
- Incorporate basic seismic and hydrological factors, simulating simple scenarios like static /dynamic load considering hydrological parameters.

E. Stabilization, Risk Mitigation, and Monitoring

- Recommend site-specific measures such as drainage systems, retaining walls, and rock bolting for slope stabilization etc ·
- Suggest monitoring using inclinometers and piezometers for periodic checks. ·
- Integrate SSA findings with Environmental Impact Assessments (EIA), preparing straightforward contingency plans for slope failures (FoS>1.5 targets).

The SSA shall be as performed per the methodology outlined in the Expert Committee report dated 28/06/2025 (Annexure-1). All work shall be executed under agreements with individual mine owners, with payments borne by them. Directorate of Geology & Mining shall oversee coordination but not payments. Legal disputes fall under Uttarakhand High Court, Nainital jurisdiction.

5. **List of Deliverables (in hard and Soft copies both) to be submitted to the Director, Directorate of Geology & Mining, Uttarakhand, Dehradun.'**

The report must be duly reviewed by the committee constituted by the IIT Roorkee for the same work**.**

a. Inception Report

- Project overview and methodology
- Work plan and timeline (including Gantt chart for SSA phases)
- Team composition and roles
- Preliminary site reconnaissance data

b. Geological Investigation Outputs

- Desktop study summary and literature review ·
- Field geological maps of mine sites (scale 1:2000 or better) ·
- Rock mass /slope mass classification such as RMR/SMR/Q slope-system
- Structural interpretation, with simple risk zoning maps

c. Geotechnical Investigation Outputs

- Borehole drilling logs and core photographs
- Rock discontinuity survey data
- Geotechnical characterization of slope materials and Laboratory test results (e.g., UCS, point load tests; Shear strength parameters etc. raw data in Excel/CSV)

d. Geophysical Investigation Outputs

- Electrical Resistivity Tomography (ERT) maps ·
- MASW velocity profiles ·
- Interpretation of subsurface geology (e.g., weak zones/fault/fractures etc)

e. Integrated Slope Stability Assessment

- 2D geological and geotechnical models (e.g., in Slide2 or RS2 format)
- Identification of potential failure mechanisms
- Stability analysis reports using LEM/FEM (FoS calculations under static/dynamic/hydrological loads) ·
- Kinematic analysis

f. Slope Stabilization and Mitigation Plan

- Recommendations for drainage systems Monitoring framework (sensor plans) ·
- Site-specific stabilization measures and engineering solutions for safe slope
- Contingency plans integrated with EIA

g. Final Technical Report

- Comprehensive documentation of investigations (narrative, figures, appendices) ·
- Summary of findings, recommendations, and slope redesign
- Basic risk zones mapping and hazard classification
- Appendices with raw data, maps, and modeling outputs ·
- Executive summary for stakeholders (5-10 pages, with visuals)

h. Presentation and Stakeholder Workshop

- Slide deck summarizing key findings (PowerPoint, 30-50 slides) ·
- Interactive session with government and mining stakeholders ·
- Q&A and feedback integration report

All deliverables must be submitted within four months (as per work plan), in both hard (bound volumes) and soft (PDF, basic GIS files, model files) formats including IIT Roorkee (third-party appraisal) review report, certifying compliance and suggesting revisions if needed.

6. **C**riteria for Selection of Competent Private Sector Companies for Conducting Slope Stability Analysis (SSA) in Approved Mining Leases Based on In-situ Rock Formations in different districts of Uttarakhand :

Technical Criteria for Selection:

a. **Technical Expertise**:

The firm must have qualified professionals including atleast :

I. One **Geotechnical Engineer/Mining Engineer** with a Master's degree and minimum five years of experience in relevant field.

II. One **Geologist** with a Master's degree and minimum five years' experience in mapping and also have good understanding of structural geology, Engineering geological mapping, fault line, lithology and ground water behaviour, characterization of rock mass/slope mass.

III. GIS and Remote Sensing Experts: For terrain modelling and risk zoning.

IV. Supporting staff proficient in data collection and software analysis.

b. Instrumentation and SoftwareProficiency:

V. Surveying Tools: Use of Total Station, Differential GPS (DGPS), LiDAR, and UAV-based for terrain mapping (Large Scale).

VI. Geotechnical Instruments: Ability to install and monitor slope inclinometers, piezometers, and extensometers and/or other sensors suitable to particular mine site.

VII. Numerical Modeling Software:

Limit equilibrium method (LEM) tools like Roc science Slide2

Finite element method (FEM) tools like PLAXIS2D/3D, RS2 etc. and/or

3D Slope Modeling and analysis tools such as Geo Studio or FLAC, RS3 etc.

c. Field Investigation Capacity:

VIII. Core Drilling and Soil and rock Sampling: Access to drilling rigs for obtaining soil/rock samples at various depths.

IX. In-situ Testing: Conducting SPT, CPT, pressure meter, permeability, and shear strength tests on-site.

X. Lab Testing Facilities: In-house or collaboration with NABL-accredited labs/ Institutes like IITs, NITs, CSIR Lab, reputed educational institute or laboratory (Having experience of handling similar work) for UCS, Tensile strength, triaxial, direct shear, and soil classification tests.

d. Experience in Slope Stability Analysis:

The key consultants must have a minimum of 5 years of experience in conducting slope stability analysis in hilly or mountainous terrain or similar geologically sensitive regions. Ability to incorporate hydrological data analysis.

e. Past Project Credentials:

The applicant must have successfully completed atleast three similar projects for government/semi- government organizations or reputed private firms in the last five years.

Copies of work orders and completion certificates must be submitted.

f. Registration and Legal Standing:

The firm should be a registered legal entity in India.

Must not have been blacklisted or debarred by any government agency.

g. Financial Capacity:

The firm should have a minimum average annual turnover of INR fifty lakh during the last three financial years.

Audited financial statements must be submitted as proof.

h. Work Plan and Methodology:

Applicants must submit a brief technical proposal, including methodology, timeline, data collection strategy, and analysis approach prepared in accordance to the methodology submitted by Expert committee in its report dated 28/06/2025 which is annexed with this document as **annexure**.

i. Local Engagement:

Preference will be given to firms willing to engage with local experts or institutions based in Uttarakhand for data coordination and site access facilitation.

j. Reporting and Compliance:

Preparation of detailed SSA Reports incompliance with:

Honorable National Green Tribunal guidelines

The geological report must incorporate the recommendations submitted by the multi- institutional committee constituted by the Secretary, Department of Mines, Government of Uttarakhand, in compliance with the order passed by the Hon'ble High Court of Nainital.

DGMS (Directorate General of Mines Safety) standards

Central Government/Uttarakhand State Government Acts/Rules

Risk classification, safety factor (FoS) interpretation, and slope redesign recommendations. Representative section at least every 50 meters should be taken for SSA.

Submission of slope monitoring and mitigation plans.

k. Environmental and Safety Integration

Integration of Slope Stability Analysis findings with Environmental Impact Assessments (EIA).

Development of Slope Failure Contingency Plans and mitigation measures (e.g., retaining walls, drainage systems, shotcrete, mesh anchoring).

To operate effectively in Himalayan mining leases, private firms must blend technical expertise, advanced tools, regional experience, and regulatory understanding. The ability to model dynamic and complex slope behaviors under Himalayan geoclimatic conditions are essential to ensure safe and sustainable mining practices.

It is also to be communicated that IIT Roorkee shall review the Slope Stability Analysis reports submitted by private companies. Therefore company will approach to the Committee, at IIT Roorkee and will ensure to get clearance from the committee constituted by IIT Roorkee for this work.

The company will make an agreement having legal entity with individual mine's owner before commencing the SSA work. The payment for the SSA work is born by the individual mine's owner and Directorate of Geology & Mining is not responsible for any payment related issue.

Any legal dispute shall be solely under the jurisdiction of Uttarakhand High Court Nainital.

7. Empanelment Process:

A- Company which apply for empanelment and fulfill the above-mentioned criteria shall be short listed by the committee. The short listed companies shall be communicated through Email.

B- Short listed company will make a presentation to the selection committee on an appointed day. Company will also present of rate of work in per hectare basis.

C- The presentation shall include the company's credentials, technical manpower, relevant experience, client's profile; latest technique also includes technical criteria mentioned above etc.

D- Seeing the presentations, the selection committee shall technically qualify the company based on technical criteria mentioned as above**.**

E- Selection of companies for empanelment: It is proposed to empanel maximum agencies for a period of five years, which may be reviewed for further extension.

If any suggestions are proposed, please send them to the Chairman of the Selection Committee via email ***dir.ukdgm@gmil.com***

It has been decided that the committee will hold its meetings every Monday until December 29, 2025, to review and finalize applications received during the preceding week. The committee will then forward its recommendations to the concerned officer for further action. In light of this, it is suggested that you ensure your applications are submitted at the earliest possible opportunity.

8. Applying for the empanelment:

If your company fulfills the above criteria and has the capability to carry out the activities mentioned in the scope of services, you are requested to submit your details including the following information to reach us on or before **December 27, 2025** only in the prescribed application format, which is available as annexure.

1. Year of incorporation and detailed Company profile.
2. Annual turnover for last three years.
3. List of offices Main office, Branch offices in Uttarakhand.
4. In house facilities Location wise – including number of employees with break-up or how many in slope stability analysis clients servicing.

5. List of relevant field clients–especially government sector, public sector followed by private sector with customer appreciation letters.
6. A 500 word write up on how you will perform the slope stability analysis work of mining lease area in stipulated time frame.

The above information & documents should be sent in an envelope superscripted **“Empanelment of Companies for SSA”** so as to reach the following address by **27 December, 2025**.

“Chairman, Selection Committee, Directorate of Geology & Mining, Uttarakhand, Khanij Bhawan, Bhopalpani, Raipur-Thano raod, PO Badasi, Dehradun, Uttarakhand.”

The **sealed envelopes will be opened by the Committee at 2:00 PM every Monday up to 29 December 2025.** If this date falls on a public holiday, the opening will be postponed to the next working day.

APPLICATION FORM TO APPLY FOR SLOPE STABILITY ANALYSIS STUDY OF INSITU BASED MINING LEASE AREA LOCATED IN VARIOUS DISTRICTS OF UTTARAKHAND

1. Applicant Details

Name of Company/ Organization	___________________
Type of Company/ Organization	☐Government ☐PSU ☐Private ☐Partnership ☐Other: ________
Year of Establishment	___________________________
Registration / License No.	___________________________
Address	____
Contact Details	Phone: ___________ Email: ___________
Branch Office in Uttarakhand Address	
Contact Details	Phone: ___________ Email: ___________
Other Relevant Information	

2. Detailed company profile to be attached: - YES/NO

3. Annual Turnover for last three years to be attached: - YES/NO

4. Relevant Work Experience

Project Title	Client/Department	Year	Role / Scope of Work	Deliverables

5. Project / Investigation Details

Proposed Title of Work	____

Location of Investigation Site	____
District / State	____
Coordinates (if available)	Latitude: ________ Longitude: ________
Proposed Duration & Deliverables	____

6. Equipment, Instruments & Software Availability

Field Equipment	____
Geophysical Instruments	____
GIS / Modeling / Geological Software	____
Laboratory Tie-ups	____
Others Relevant Information	

7. In house facilities location wise- including number of employees with breakup or how many technical personals are employed for slope stability analyzers works

8. List of relevant field clients- especially government sector, public sector followed by private sector (please attach customer appreciation letters)

9. Work Plan & Methodology (To be attached with application)

Provide a brief description of the approach, techniques, and methodologies that will be adopted to carry out the geological investigation, including fieldwork, sampling, testing, analysis, and final reporting.

10. Environmental & Safety Integration (To be attached with application)

Describe how environmental protection and occupational safety measures will be integrated into the proposed work plan. Include compliance with relevant laws, safety protocols, waste disposal methods, and environmental impact mitigation strategies.

11. Supporting Documents (attach as applicable)

For Organizations:

☐Registration Certificate ☐GST/PAN ☐ISO/Quality Certifications

Additional:

☐Project Reports ☐Published Research Papers ☐Training Certificates

12. Five hundred word write up on how you will perform the slope stability analysis work of mining lease area in stipulated time line- Attached : - YES/NO

13. Declaration

I/We hereby express interest in undertaking the geological investigation as per the details provided above. The information submitted is true and correct to the best of my/our knowledge.

Signature of Applicant / Authorized Signatory:

Name: ____

Designation (if applicable): __________________

Seal/Stamp (if organization): _________________

Date: ___ / ___ / 20___

Place: ____

Expert Committee Report

On

The Impacts Of Mining Operations On The Ecological And Environmental In The Light of Seismic Stability

Constituted

By

Secretary, Industrial Development (Mining) Government of Uttarakhand

Report on the impacts of mining operations on the ecological and environmental in the light of Seismic Stability

The Secretary, Industrial Development (Mining) Government of Uttarakhand vide his letter no. 465/VII-A-1/2025-09(104/2023) dated 18.02.2025 and amended letter no. 482/VII-A-1/2025-09(104/2023) dated 20.02.2025 had constituted an Expert member committee in compliance of the order dated 01.11.2024 issued by Hon'ble National Green Tribunal on original application no. 78/2023 Durga Singh Panwar vs Government of Uttarakhand and others. In this order, as Expert member committee had constituted to study the impacts of mining operations on the ecological and environmental stability of various geo-tectonic areas (Geo-tectonic zones) within the state in the light of seismic stability. The set Expert committee had members of following Institutes:

1. Senior Specialist Scientist nominated by Director, Wadia Institute of Himalayan Geology, Dehradun - Chairman.
2. Senior seismologist nominated by Dy D.G., Geological Survey of India, Dehradun - Member
3. Environment subject expert and Geotectonic subject expert nominated by Director, Indian Institute of Technology, Roorkee - Member
4. Senior Specialist Scientist nominated by Director, Indian Institute of Remote Sensing, Dehradun - Member
5. Joint Director, (Garhwal), Geology and Mining, Uttarakhand – Member Secretary

The constituted committee has held its first meeting in the premises of the Wadia Institute of Himalayan Geology Dehradun on 27.02.2025 at 11 AM. The following nominated members have attended the meeting:

1. Dr.Vineet Gahalaut, Director, Wadia Institute of Himalayan Geology (WIHG), Dehradun.
2. Dr.Naresh Kumar, Senior Geo-scientist, Wadia Institute of Himalayan Geology, Dehradun.
3. Prof. Anand Joshi, Earth Sciences, Indian Institute of Technology, Roorkee
4. Dr.PawanGautam, Senior Geologist, Seismic Studies Division, G.S.I. Lucknow(through Videoconferencing).
5. Dr.R.S.Chatterjee, Senior Scientist, Indian Institute of Remote Sensing, Dehradun.
6. Mr.G.D.Prasad, Joint Director, (Garhwal), Directorate of Geology and Mining, Uttarakhand.

Apart from the members the following officials of the Geology and Mining, Uttarakhand had also attended the meeting to assist and furnished the data of mining activities of Uttarakhand.

1. Mr. Dinesh Kumar, Joint Director, Geology and Mining, Uttarakhand.
2. Mr. G.N. Khanduri, Senior Administrative Officer, Geology and Mining, Uttarakhand

After the first meeting, the committee conducted its sessions on 5 March 2025, followed by meetings on 1 May 2025 and 24 June 2025.

Brief Introduction of the geo-tectonic and seismicity: Uttarakhand state has two important geo-tectonic divisions: the Himalayan belt and the Indo-Gangetic plains (IGP). These two divisions are demarcated by the Himalayan Frontal Thrust (HFT), tectonic boundary separating Himalayan wedge from the plains. The districts Haridwar, Udam Singh Nagar and Haldwani area of Nainital district predominately fall in the frontal Himalaya under Indo-Gangetic division. Remaining districts of Uttarakhand are located within Himalaya belt. Himalaya region is geotectonically a complex zone having seismic activity due to the collision of the India and Eurasia tectonic plates. Further, the Himalayan mountain belt is sub-divided into four geotecotnic units with division parallel to the Himalayan arc. Adjacent to the IGP to the north HFT, Siwalik Himalaya has sedimentary and meta-sedimentary rocks of younger Himalayan geological rock formations. Siwalik Himalaya is separated from Lesser Himalaya to its north by the Main Boundary Thrust (MBT) which is seismically more complex. Further north, the Higher Himalayan rocks are divided from Lesser Himalaya by Main Central Thrust (MCT) and to its north, Tethys Himalaya exists which is demarked by South Tibetan Detachment (STD). Geologically, the complexity in tectonics and geological rock age increases towards the higher Himalaya. Also, the mineral prospects (in-situ minerals) of different types are proportionally more towards high Himalayan mountains.
Districts near the MCT, mainly Pithoragarh, Chamoli, Uttarkashi and Rudarprayag, are within high tectonic stress concerning seismic stability. In-contrast, districts like Dehradun, Tehri, Pauri, Almora and Bageshwer experience relatively less tectonic stress and low seismic activity. Therefore, monitoring of seismicity to micro-earthquake level is an important aspect concerning to seismic stability to the mines.

Mining Activities in Uttarakhand:
Mining activities being carried out in Uttarakhand, there are two types of mining in the state: (1) River bed mining and (2) In-situ Open Cast mining for minerals soapstone, magnesite and Silica sand.

In River bed mining, the policy and Uttarakhand minor mineral rules permit maximum depth of three meters or up to the ground-water level, whichever is less. In Forest areas, the Uttarakhand Forest Corporation executes river bed mining, protecting 25 percent of the area from each bank of the river and mining only 50 percent of the area at the centre part of the river. In revenue/private Nap Bhumi (private land) areas, 15 percent or 10 meters of the area from either side of the River bank must be protected as a non-mining area.

Total about 6569 hectare area have been marked /identified as river bed mining lots in different districts of Uttarakhand. Out of which about 5796 hectares area falls in four plain districts viz Dehradun, Haridwar, Nainital and Udamsingh Nagar. A total of about 5796 hectares identified area for river bed mining about 3381 hectares area are presently under mining lease and about 2415 hectares area are recently identified and are under process of mining lease. The total area of four plain districts about 5077 hectares area is allotted to Uttarakhand Van Vikas Nigam and rest about 719 hectares areas to other Nigams/private individuals/companies. In hill districts viz Uttarkashi, Tehri, Pauri Garhwal, Rudarprayag, Chamoli, Pithoragarh, Bageshwar, Almora and Champawat, total about 773 hectares have marked /identified as river bed mining lot out of which about 636 hectares area are executed by Uttarakhand Forest Corporation, and the remaining about 137 hectares are to be mined by Garhwal Mandal Vikas Nigam, Kumaon Mangal Vikas Nigam and private individuals.

The Uttarakhand Forest Corporation conducts a replenishment study every year after the rainy season to ensure ecological sustainability from Central Soil Conservation Institute Dehradun.

As communicated by Directorate of Geology & Mining, Uttarakhand, the state Government has granted leases for insitu mining in various districts, with the following details:

Sr. No.	Name of district	Number of issued mines	Minerals for which Mines are issued
1	Bageshwar	169	Soapstone, Magnesite
2	Pithoragarh	28	Soapstone, Magnesite
3	Chamoli	8	Soapstone
4	Uttarkashi	1	Silica sand

These mines are executed as open-cast mining. The depth of the mining is not restricted and it may go up to the depth where the minerals can be found. The mining licence shall be allotted after the mining plan approved by the Director, Geology and Mining, Uttarakhand and subsequently the environment clearance is issued by the committee constituted by the Ministry of Environment and Forest, Government of India. After the mining licence is issued by the Government of Uttarakhand, the UKSPCB issues

Concerned to Operate to the lessee. Then only the mining activity is allowed to the lessee by the district mining officer.

The Joint-Director Geology and Mining communicated that, apart from River bed mining, several mining leases have been issued for extraction of soap-stone, magnesite and silica-sand minerals found in in-situ rocks in Bageshwer, Pithoragarh, Chamoli and Uttarkashi districts.

The committee had intensively discussed the issue of Open-Cast in-situ mining activities in Himalayan belt and found that the areas are falling near high tectonic stress areas. Since the depth of the mining is also not restricted and it depends on the availability of the minerals, the committee also discussed the over-burden generated by the lessee during mining operation.

The production of mineral data provided by the Directorate of Geology & Mining is tabulated as under:

District	Mineral Extracted	Year-Wise Production of Mineral in last Five Years				
		2020-21 (In Ton)	2021-22 (In Ton)	2022-23 (In Ton)	2023-24 (In Ton)	2024-25 (In Ton)
Bageshwar	Soap stone	324794	350602	461336	386663	265480
	Magnesite	21392	27726	36872	32162	19056
Pithoragarh	Soap Stone	33755	27496	28136	29264	29819
	Magnesite	-	-	-	14190	19393
Chamoli	Soapstone	1193	1014	11642	9912	11157
Uttarkashi	Silica sand	Nil	Nil	Nil	Nil	Nil

Discussion on techniques available for seismic safety required in the in-situ open cast mining:

The committee discussed about the seismic mining modelling and monitoring of micro-seismic activity in areas where clusters of in-situ Open-Cast mining are executed. The committee suggested that following aspects need to be looked into:

1. **Mining induced seismic activity, 2. Mining induced deformation, 3. Seismic induced slope stability**

The committee requested Indian Institute of Remote Sensing (IIRS-ISRO), Dehradun to prepare a background detailed note on monitoring of mining induced deformation using satellite imaginaries. Indian Institute of Technology Roorkee was requested to prepare a background detailed note on the analysis of mining induced slope stability through simulation and modelling for existing mining areas and also asked Wadia Institute of Himalayan Geology, Dehradun to prepare a background detailed note on real time monitoring of mining induced micro earthquake activities through local seismic network.

The committee requested the Directorate of Geology & Mining to provide geological study reports of mining areas in recent years. In response, DGM submitted a report containing geological study reports of 62 mining leased areas in District Bageshwar.

Report reveals that almost all the mines show unscientific mining methodology adopted by mine owners which had adversely modified slope. Absence of benches leads to debris slides at pit boundaries. Few of them triggered landslides at the pit boundaries which are affecting agriculture land and habitation downside the slope. Huge debris is being accumulated in downhill side which flows in natural streams and causing chocking of water flow in streams.

Detailed note has been submitted by Dr. R.S. Chatterjee, Scientist 'G', Head Geosciences Department & Group Director Geosciences and Disaster Management Group, Indian Institute of Remote Sensing (IIRS), Dehradun, Dr. S P Pradhan, Associate Professor, Department of Earth Sciences, IIT Roorkee, and Dr. Naresh Kumar, Senior Scientist, Wadia Institute of Himalayan Geology, Dehradun to the Member secretary of the committee. **These notes are annexed at the end of this report.**

The Directorate of Geology & Mining provided the locations of the in-situ mines. The IIRS, Dehradun, placed the point locations of mining on a high-resolution satellite image along with leasehold areas available for the mining locations in and around Bageshwar. Both the point locations of mining and leasehold areas were available from the State Geology & Mining. IIRS has also provided information about the data required for time series DInSAR processing (used for land surface displacement monitoring) and the sources for downloading the data. In this case, some data are freely available. Data processing methods, merits and demerits of the techniques for studying land surface deformation over the study area are also mentioned. It is recommended to adopt an advanced DInSAR technique such as PSInSAR or SBAS InSAR for detecting, monitoring and characterising land surface deformation potentially due to mining, if any, during the last couple of years to reveal the present status of land surface deformation in and around the mining areas. The deliverables of the study should include: (1) present status of land surface displacement in and around the mining areas of the study area, (2) cumulative land surface displacement map during 2021-2024 for the three study areas (e.g., Bageshwar, Pithoragarh and Chamoli). (3) land surface deformation history for a couple of significantly subsiding areas in and around the mines for characterisation of mining-induced subsidence.

IIT Roorkee provided a detailed document about slope stability assessment in open-pit mines located in hilly and mountainous terrain, particularly in geologically sensitive and seismically active regions. It is highlighted that ensuring the stability of both mine slopes and waste dumps is essential not only for the safety of workers and equipment but also for maintaining economic viability and minimizing environmental impact. In this regard, a detailed and multidisciplinary investigation is essential to understand and mitigate slope stability risks. The objective of this investigation is to assess the condition of the rock mass, subsurface characteristics, and potential failure mechanisms that could affect the long-term stability of mine slopes. The study requires geological, geotechnical and geophysical investigation for the slope stability assessment. Under the geological investigation, desktop study, filed geological mapping, rock mass classification and photogrammetry and remote sensing are to be performed. Geotechnical investigation requires drilling and core logging, laboratory testing and rock discontinuity survey. In the geophysical investigation, seismic reflection, electrical resistivity tomography (ERT) and Multichannel Analysis of Surface waves (MASW) will be performed to obtain the subsurface geophysical properties related to slope stability. In this filed data collection, data processing and interpretation and integration and modelling are the works to be performed. Thereafter, slope stabilization and risk mitigation measures has to be done through drainage management, monitoring and early warning systems and controlled blasting techniques. It is highlighted that in complex and geologically active terrains such as the Himalayas, ensuring slope stability is a multifaceted challenge that demands a systematic and interdisciplinary approach.

Wadia Institute of Himalayan Geology, Dehradun provided the detailed information for Conducting micro-earthquake (MEQ) studies in and around the mining areas of Chamoli, Bageshwar and Pithoragarh, Uttrakhand. It highlights the background seismic activity of the region and mentioned about the requirement of conducting these surveys through a local seismic network. There is requirement of assessing micro- and higher earthquake occurrences in and around ~100 km around the mine areas. It is highlighted that mine areas fall under IV and V, the highest seismicity zones in the seismic zoning maps of India. It is proposed to for a need of a local seismological network comprising at least 8 broadband seismological stations covering ~100 km square area around mining areas with tentative locations of the stations. The local earthquake data will be analyzed to obtain hypocentral parameters (source positions in terms of latitude and longitude, source depth, origin time etc.) and also magnitudes. These earthquake data will be studied for earthquake swarm activity, status of seismicity before, during and after the mining activity and report the background seismicity. The earthquake source geometry will be obtained to correlate with the tectonics of the study region. The document highlights about the aim of study, proposed seismic network, work plan to carry out the field and the laboratory works. There is need to install the seismic stations based on the requirement of the present work, process the data on daily basis and report about the background seismicity, enhanced earthquake activity, swarms etc.

The committee reviewed the data of all the mining areas allotted/under process of allotment presented by the Geology and Mining Department, Uttarakhand.

The committee unanimously agreed that there is no threat to seismic stability in the River bed mining activities through manual methods and up to the depth mentioned in the present policy that is up to 3.0 meters in the Indo-Gangetic plains, that is Udhamsingh Nagar and Haridwar districts of Uttarakhand. And also, there is no threat in River bed mining activities in Dehradun, Nainital, Tehri, Pauri-Garhwal, Almora and Bageshwer areas.

The issue of mining activities in river bed areas near high tectonic stress zones was thoroughly discussed. The committee concluded that since the area under river bed mining is small and the depth of excavation is only a maximum of three meters, the banks are protected by in-situ rocks or by Breast wall, making the effect on seismic stability negligible. The stress change caused by such activity at seismogenic depth is insignificant to cause/trigger seismicity in the region.

The committee unanimously agreed that river bed mining shall be permitted subject to condition that the concerned departments of the Government of Uttarakhand ensure the ecological and environmental sustainability by periodic monitoring.

The committee directed the Geology and mining department, Uttarakhand to revisit the river bed mining areas and ensure that the banks are protected either by the in-situ rocks or by Breast walls to check the toe-erosion.

Observations of the committee are as follows:

1. The committee has noted that mining operations needs to be conducted in prescribed scientific manner, and overburden material needs to be disposed of systematically, with strict avoidance of debris dumping into streams. Additionally, committee noted deformation signatures in several mines. Given that the state falls under seismic zones 4 and 5, special precautions are necessary during in situ mining activities.

2. It appears that, in general, there is a lack of advanced scientific monitoring systems to track potential natural hazards in mines and to implement timely corrective measures.

Recommendations of the committee:

1. The committee unanimously agreed that riverbed mining may be permitted. The state government must ensure periodic monitoring in accordance with the rules and standards prescribed by the relevant authorities.

2. To ensure seismic safety of the in-situ mining operations, the committee recommends implementing a robust monitoring system to track potential hazards along with the adoption of best practices in in-situ mining. In this regard, following monitoring methods/systems need to be implemented:

(i) **Micro earthquake monitoring** must be conducted in mining prone areas using a local seismic network.

(ii) SAR based **satellite technique** must be employed to monitor ground deformation caused by mining activities or slope subsidence.

(iii) **Slope stability analysis** of existing and proposed mining sites must be carried out, and the findings should be reviewed by a recognized academic or research institution of national repute. Mining Plan must incorporate the recommendations arising from this analysis. Furthermore, the state government should implement a system of **periodic field inspections** to ensure the effective execution of the Mining Plan on the ground.

It is expected that by adopting these measures, risks associated with mining activities in seismically sensitive areas may be mitigated.

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Recommendation

Conducting micro-earthquake (MEQ) studies in and around the mining areas of Chamoli, Bageshwar and Pithoragarh, Uttrakhand

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Background:

In response to the interim order dated 08 November 2024 passed by the Hon'ble National Green Tribunal in the Original application No. 78/2023 of Durga Singh Panwar vs. State of Uttarakhand and others, the Industrial Development (Mining) Department, Govt. of Uttarakhand has constituted an Expert Committee for recommending guidelines for evaluating ecological and environmental stability of various geo-tectonic zones in Uttarakhand to study the impacts of mining operations in the light of seismic stability of the region. The committee recommended conducting micro-earthquake (MEQ) studies in and around the mining areas of Chamoli, Bageshwar and Pithoragarh are of Uttarakhand.

Duration of the Project: Pre-, post and during mining periods

1. Introduction:

Uttarakhand is a Himalayan mountainous state, richly endowed with a variety of mineral resources, including both major and minor minerals. However, the extraction of these minerals poses significant risks due to the state's geographical location. The region falls under seismic zones V and V, which are considered highly earthquake hazard zones of India. As a result, mining and associated blasting activities in this region need substantial precaution. The state has experienced several strong earthquakes in the past, such as the 1991 Uttarkashi (Mw 6.8) and 1999 Chamoli (MW 6.5) earthquakes, which caused extensive damage to life, property, and infrastructure (Cotton et al., 1996, Kayal et al., 2003). Also, the seismological studies by different agencies highlight seismic belt in the Lesser and Higher Himalaya micro-, low- and moderate magnitude earthquakes (Kumar et al., 2012; Babu et al., 2023). These events highlight the vulnerability of the region and emphasize the need for cautious and sustainable mining practices.

The Directorate of Geology and Mining, Government of Uttarakhand, has planned to initiate mining operations in Chamoli, Bageshwar and Pithoragarh regions. In light of the seismic sensitivity of the region, it is both prudent and essential to implement a robust scientific monitoring framework that can track and analyze seismic activity during the entire course of mining operations, before its start and after the mining period. Responding to the Directorate's request, the committee recommends a comprehensive seismological monitoring and risk assessment by the agency nd experts having its domain expertise and long-standing experience in seismicity monitoring across the Himalayan belt.

In view of this, it is proposed to for a need of a local seismological network comprising atleast 8 broadband seismological stations covering ~100 km square area around mining areas. These stations will be installed after site selection and construction of the hut/pillar at each station. The tentative locations of the stations are given in Figure 1. The location will be finalized after the selection of sites and noise survey. These stations will record data in continuous mode. The data will be archived at through the GPRS system. The local earthquake data will be identified, extracted, and will be analyzed for the estimation of hypocentral parameters. The local earthquake data will be analyzed to obtain hypocentral parameters (source positions in terms of latitude and longitude, source depth, origin time etc) and also magnitudes. These earthquake data will be studied for earthquake swarm activity, status of seismicity before, during and after the mining activity and report the background seismicity. The earthquake source geometry will be obtained to correlate with the tectonics of the study region. The details of the proposed work are given below.

Aims:

- To monitor the micro-earthquake activity in and around Chamoli and Pithoragarh mining region by establishing total 6 new seismological stations for the duration of the mining work.
- To understand the seismo-tectonic setup of the area in a precise manner by deciphering the location of earthquakes, source geometry and characterization of various faults and lineaments around the project.
- Analysis and interpretation of data for estimation of the *a* and *b* value estimation from G-R relation.
- To develope a seismotectonic map based on MEQ study.
- To prepare a MEQ study report to be submitted to Directorate of Geology and Mining, Uttarakhand

2 Proposed Seismic Network:

The tentative locations of proposed stations surrounding the mining sites are given in Fig. 1. Eight Broadband seismographs are reqiored to monitor the earthquake activity from micro-earthquake size.

It is necessary to place the stations around the seismic activity to be monitor for proper identification of the earthquake event and its appripraite source characterization.

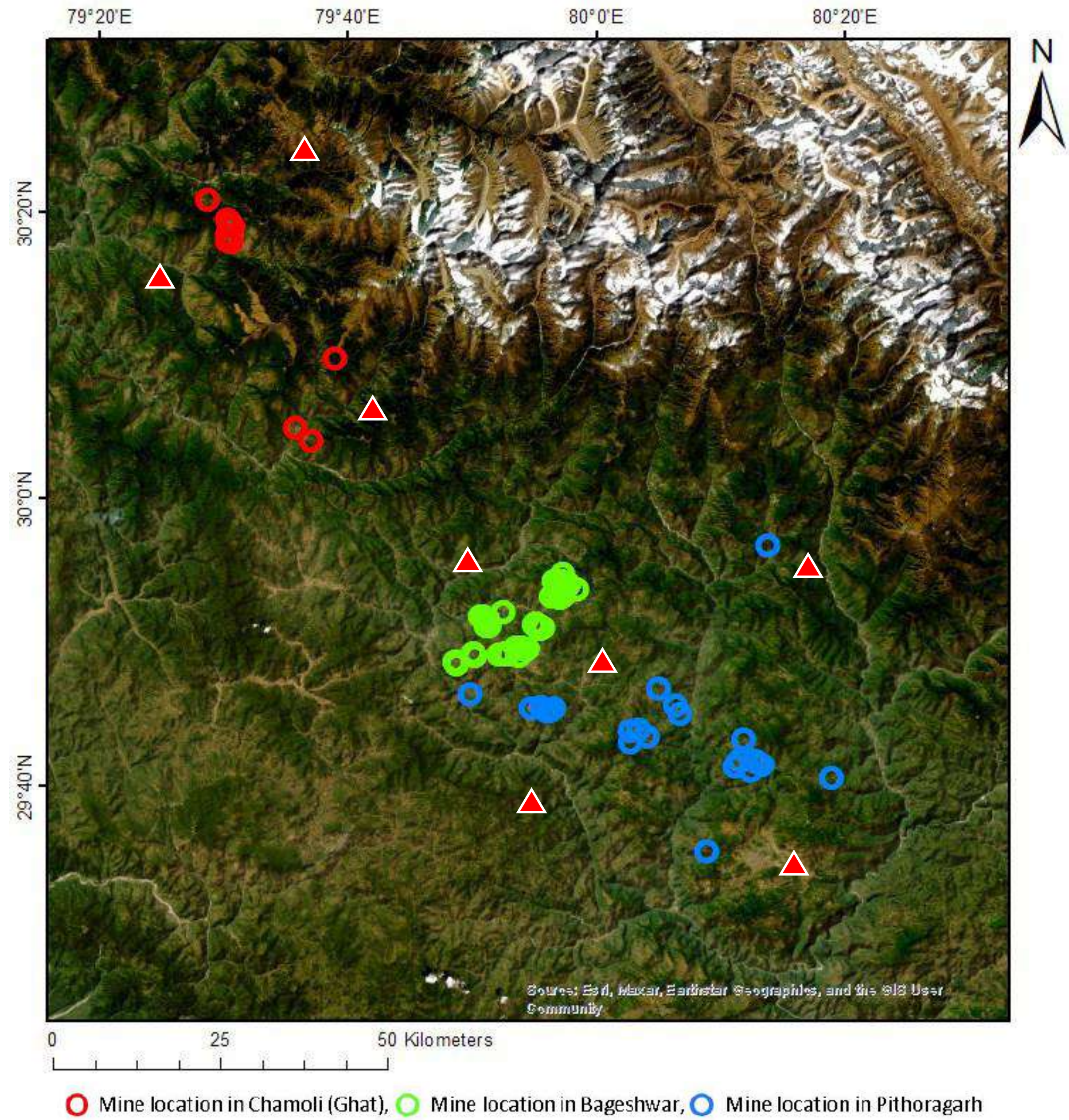

Figure 1. Map showing mining sites in Chamoli, Bageshwar and Pithoragarh along with proposed seismological stations (red triangles) plotted over high resolution satellite image prepared by IIRS, Dehradun
(Mining points locations are provided by Uttarakhand state Geology and Mining Directorate)

In the present study, the earthquake activity has to be monitored in and around the mining locations in Chamoli, Bageshwar and Pithoragarh of Uttarakhand, the information provided are provided by Uttarakhand state Geology and Mining Directorate. This local seismic station network is proposed to cover all the mines locations for reporting earthquake activity to the micro-earthquake size. Atleast one station is close to the locations of the mines so recording all the earthquakes.

3. PROPOSED WORK PLAN

Field Work:

(i) Site selection/ Finalisation for installation of the instrument

Monitoring of earthquake activity requires a seismograph network with seismic stations located within and around the study region. According to the requirement by Directorate of Geology and Mining, Uttarakhand, eight seismic stations are planned with tentative locations shown in Figure 1. The seismic station is required to be installed on a hard bedrock to extract the seismic signal with the highest signal-to-noise ratio (SNR) at the proposed site. Therefore, a survey will be performed to select and finalize the location of the seismic stations.

(ii) Noise survey on the selected sites and installation of the instrument

For the finalization of the seismic station, there is a requirement for noise survey at different points of the proposed site. After site identification, seismic data will be recorded by the seismic instrument to obtain the noise level and assess the signal strength. The site will be finalized to qualify the standard level of recording the micro-earthquake activity. The instrument will be installed on a concrete pillar erected from the hard bedrock to enhance the SNR.

(iii) Specification of the Seismograph and the components of the seismic station

A broadband seismograph will be installed and each station will include the following components

a) Seismic sensor
b) Data Acquisition System (DAS)
c) Batteries, Solar panel and charge controller for continuous power supply
d) IGM/GPRS system for data communication from remote stations.

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(iv) Extracting and archiving the seismic data

The seismographs will be installed to record the continuous seismic data at each seismic station. This data will record all the earthquake events of the detection level of the seismic network. The seismic network is planned in such a way that it can record high-quality micro-earthquake data for all the earthquakes of magnitude 1 and higher size to occur at the mining site and around within ~30 km radius.

Laboratory Work:

(i) To download the continuous data from the digital seismographs

Continuous seismological data will be extracted and archived at Institute headquarter Dehradun through the GPRS communication system. Extraction and identification of earthquakes mainly of micro-earthquake size require scanning of continuous-time series of each seismograph on a regular and daily basis. Data from different stations will be combined and processed for further analysis.

(ii) To identify the different seismic phases from the extracted seismic data

The location of the earthquake and the calculation of its source parameters depends on the identification of different seismic phases from the extracted digital waveform data (Kumar et al., 2021). Computer-developed codes/software will be used to process the digital waveform data and identify the seismic phases. The main phases e.g., the P-wave and S-wave are important seismic phases for the earthquake location. These phases are used to evaluate the earthquake source location and the origin time of the earthquake occurrence. The maximum amplitude and related period of body and surface waves is used to calculate the size of the earthquake. The data will be analysed in time and frequency domains to obtain the waveform data for the quantification of the earthquake.

(iii) Processing the phase and amplitude data for earthquake location and obtaining the different parameters

Continuous seismic data recorded by these stations will be processed to extract the earthquake data. Continuous data will be collected through GPRS system (wherever possible) at central recording station for processing and archving. The earthquake data will be extracted based on signal strength denoted for a reasonable period. Earthquake data extracted from each station of a particular period will be combined for retrieving the required information of induced seismicity of the mining sites. After processing this data the information on the seismic activity of the region will be provided after each month. To retrieve the data regularly and process it for the MEQ one project assistant is required. Earthquake parameters such as origin time, epicenter, focal depth and magnitude are obtained using the combined data set. Seismic activity parameters such as hypocenter and a & b values from the Gutenberg-Richter relation will be obtained for the study region from the data recorded during the survey period of the project.

(iv) Earthquake swarm activity

Assessment of background seismic activity is important for any changes related to the mining operation. The enhancement of earthquakes relative to background seismicity can also be quantified in the form of swarm activity which can be realted to any unusual activity A swarm of earthquakes is a sequence of mostly small earthquakes with no identifiable mainshock. They are usually short-lived but can continue for days, weeks, or sometimes even months. They often recur at the same locations and in this case close ot the mines. The occurrence of such events in a single location raises significant concerns regarding the structural integrity and public safety of that region.

(v) Seismo tectonic linkage and delineation of tectonic features

The hypocenters of the earthquakes reveal close association of seismic activity with the tectonic faults of the study region (Hajra et al., 2021). The identification and location of the earthquake are important to delineate the sub-surface geometry of the faults. Identification of micro-earthquake activity increases the number of events manifold and therefore this data is very useful for the identification of the tectonic features of the study region. However, the reliability of earthquake location depends upon phase data of an appropriate number of stations. The signal strength decreases with the decrease of the size and identification of phases is difficult for small magnitude earthquakes. Our experience indicates that eight stations installed at 20-30 km distances from each other can detect the earthquake for the proper location close to magnitude 1.

Submission of the report

As proposed, detailed report of the MEQ all the work will be submitted to the Directorate of Geology and Mining, Uttarakhand for clearance of seismic design parameters of the project and presentation of MEQ studies.

References

Babu, V.G., Kumar, N., Verma, S.K., & S.K. Pal (2023). An updated earthquake catalogue and seismic regimes in the Northwest Himalaya: seismic periodicity associated with strong earthquakes. Journal Earth System Science**,** 132, 173(1-20). https://doi.org/10.1007/s12040-023-02180-4.

Hajra, S., Hazarika, D., Kumar, N., Pal, S.K., Roy, P.N.S. (2021). Seismotectonics and stress perspective of the Kumaon Himalaya: A geophysical evidence of a Lesser Himalayan duplex. Tectonophysics, 806, 228801, 1-17.

Kumar, N., Hazarika, D., and Sain K. (2021). Earthquakes: Basics of seismology and computational techniques, In Samui, P., Dixon, B. & Bui, D.T., In Ed. *Basics of Computational Geophysics*, Elsevier, USA, Chapter 4, 47-80.

Kumar, N., Paul, A., Mahajan, A.K., Yadav, D.K., & C. Bora (2012). Mw 5.0 Kharsali, Garhwal Himalaya Earthquake of July 23, 2007: Source Characterization and tectonic implication. Current Science, 102(12), 1674-1682.

Recommendations for Identifying and Monitoring Mining-Induced Land Surface Deformation in and around Bageshwar-Pithoragarh, Uttarakhand

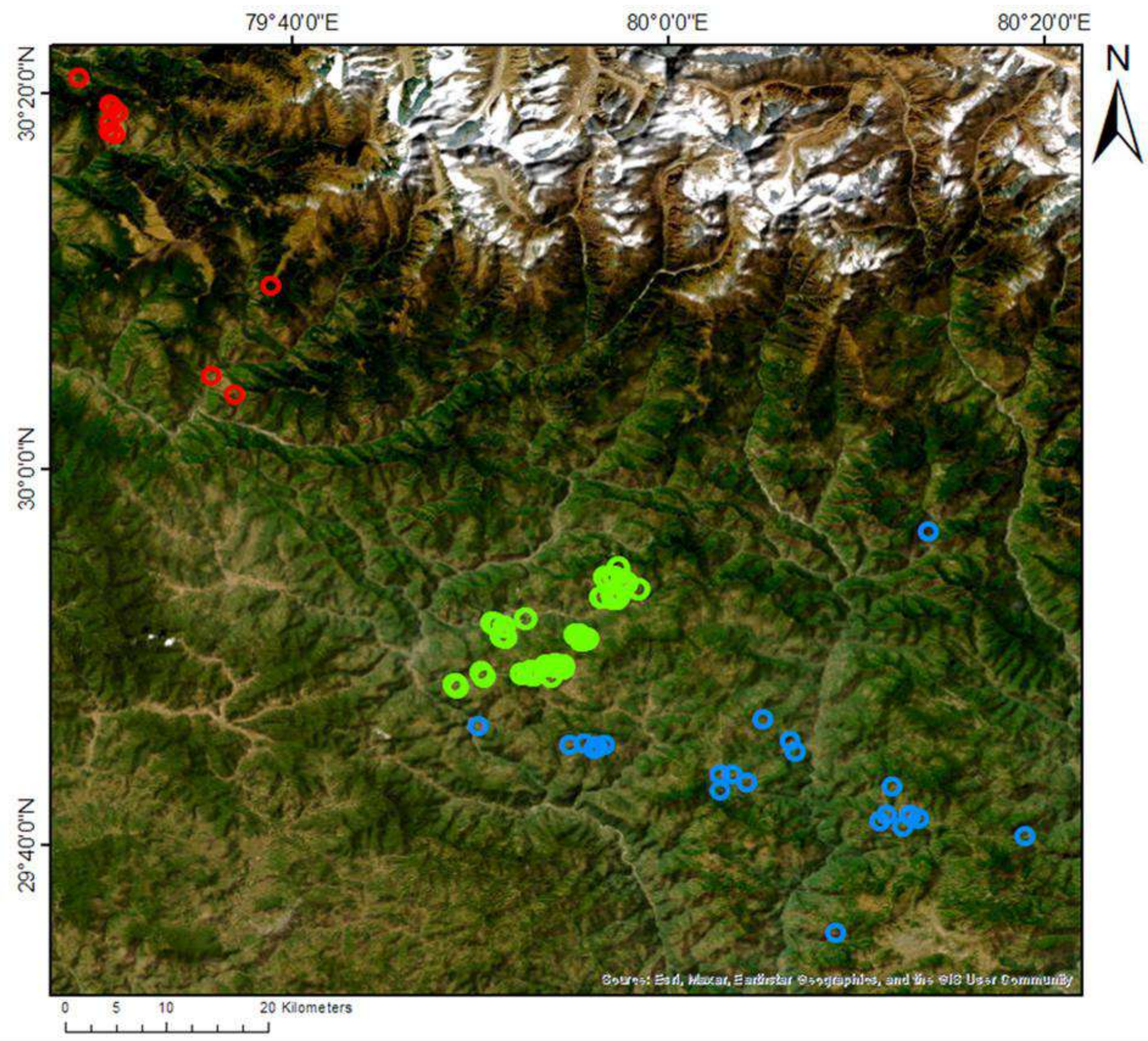
In response to the interim order dated 08 November 2024 passed by the Hon'ble National Green Tribunal in the Original Application No. 78/2023 of Durga Singh Panwar vs. State of Uttarakhand and others, the Industrial Development (Mining) Department, Govt. of Uttarakhand has constituted an Expert Committee for recommending guidelines for evaluating ecological and environmental stability of various geo-tectonic zones in Uttarakhand to study the impacts of mining operations in the light of seismic stability of the region. On this backdrop, the committee has recommended conducting a Satellite Differential Interferometric Synthetic Aperture RADAR (DInSAR) based land surface deformation study in and around the Bageshwar-Pithoragarh mining leasehold area to identify mining-induced land surface deformation affected areas, if any.

Study Area:

The study area includes in situ mining leasehold areas and neighbouring habitat regions in Bageshwar, Pithoragarh and Chamoli (Ghat), Uttarakhand, to evaluate the present status of land surface deformation potentially due to mining operations. Since the precise leasehold outlines are not available for all the mining locations, the point locations of mining are placed on a high-resolution satellite image (Fig. 1a). Further, in an extended view, the leasehold areas available for the mining locations in and around Bageshwar are shown (Fig. 1b). Both the point locations of mining and leasehold outlines are provided by the Uttarakhand State Geology & Mining Directorate.

Data Requirements & Availability:

For time series DInSAR processing, systematic acquisition of Synthetic Aperture RADAR (SAR) data pairs with interferometric capability will be required. Moreover, for monitoring land surface deformation, time series data stacks acquired at a regular interval will be required. Presently, X-band TerraSAR-X/TanDEM-X data from DLR-Germany and Cosmo Skymed data from ASI-Italy, C-band RISAT-1A data from ISRO-India, RADARSAT Constellation Mission (RCM) data from CSA-Canada, and Sentinel-1 data from ESA-European Union, and L-band ALOS-2 PALSAR-2 data from JAXA-Japan are available for DInSAR-based land surface deformation measurements. Out of this, Sentinel-1 data have been, in general, acquired systematically with a regular time interval of 12 days since 2017 and are freely downloadable. Other satellite-based global SAR data with interferometric capability have limited time stack acquisition or are commercial in nature, expensive and required to procure in ‘Future Programming’ mode. Sentinel-1 data are available in ascending and descending orbits for all the three study areas (e.g., Bageshwar , Pithoragarh and Chamoli-Ghat areas) as follows (Table 1), and all the data can be freely downloaded from time series DInSAR processing.



Mine location in Chamoli (Ghat), Mine location in Bageshwar, Mine location in Pithoragarh

Fig. 1(a): High resolution satellite Maxar multispectral colour composite image (ArcGIS base map) showing in situ mine locations in Bageshwar, Pithoragarh and Chamoli (Ghat) areas, Uttarakhand.
(Mining point locations are provided by Uttarakhand State Geology & Mining Directorate)

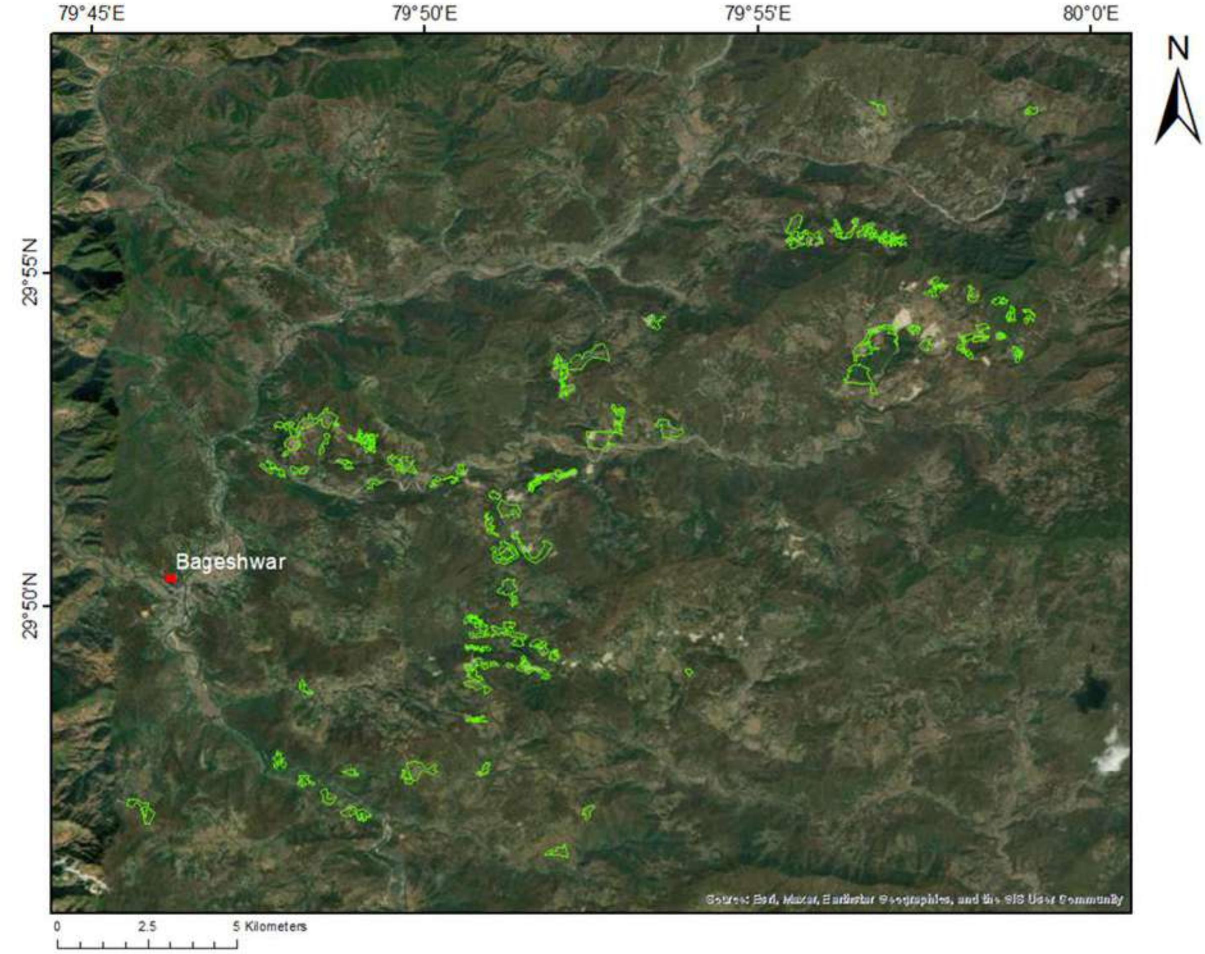


Fig. 1(b): High-resolution satellite Maxar image showing lease-hold areas (green outlines) of mining in and around Bageshwar, Uttarakhand.
(Leasehold outlines provided by Uttarakhand State Geology & Mining Directorate)

Table 1: C-Band Sentinel-1A scenes available for DInSAR-based land surface deformation measurements in three study areas

Study Area	Bageswar Area		Pithoragarh Area		Chamoli (Ghat) Area	
Imaging Specifications :						
Orbit Node Subswath (look angle) Polarisation	Descending IW3 ~ 40°-44° VV/VH	Ascending IW3 ~ 40°-44° VV/VH	Descending IW3 ~ 40°-44° VV/VH	Ascending IW1 ~ 29°-35° VV/VH	Descending IW1 ~ 29°-35° VV/VH	Ascending IW3 ~ 40°-44° VV/VH
No. of Scenes						
During 2017-2024 During 2021-2024	143 120	235 119	143 120	01 01	64 61	235 119

IW3: Interferometric Wide Swath, Sub-swath: 3; IW1: Interferometric Wide Swath, Sub-swath: 1
VV: Vertical-Vertical; VH: Vertical-Horizontal
Data can be freely downloaded from: https://search.asf.alaska.edu/#/

Data Processing Methods:

Spaceborne differential interferometric SAR (DInSAR) has been considered to be the best-suited technique for obtaining spatially continuous land surface deformation at the centimetre to sub-centimetre level. In general, conventional DInSAR is used to measure event-based land surface deformation (e.g., co-seismic deformation, landslide, mining subsidence) for discrete time-frames in the order of a few centimetres to a few tens of centimetres over an area of 10s of km x 10s of km (Massonnet et al., 1993; Chatterjee et al., 2015, 2016). Recently, wide-swath interferometric SAR data pairs acquired in ScanSAR and TOPSAR imaging modes have been advantageously used for studying land surface deformation over a large spatial extent (Fielding et al., 2013; Pranjal et al., 2021). Further, for detecting and monitoring slow deformation and for characterising the time series deformation history aimed at addressing the nature of deformation, Advanced DInSAR (ADInSAR) technique, such as Persistent Scatterer InSAR (PSInSAR), Small Baseline InSAR (SBAS) and their variants (Ferretti et al., 2001, 2011; Berardino et al., 2002; Werner et al., 2003; Perissin and Wang, 2012) are considered most suitable as such advanced techniques eliminate most of the limitations of conventional DInSAR which enables to detect, monitor and characterise deformation. Hence, it is recommended to adopt an advanced DInSAR technique such as PSInSAR or SBAS InSAR for detecting, monitoring and characterising land surface deformation potentially due to mining, if any, during the last couple of years (e.g., 2021 till date) and to reveal the present status of land surface deformation in and around the mining areas. The precision of measurement in DInSAR-based deformation results ($\sigma_{displ.}$) depends on the phase measurement uncertainty or standard deviation of phase (σ_{ϕ}) and radar wavelength (λ) which amounts to a few millimetres only. The quality of deformation rates of the advanced DInSAR techniques (e.g., PSInSAR), however, depends on the residual phase variance of the pixels, controlled by the temporal coherence of the data stack.

Deliverables:

The deliverables of the study should include: (1) present status of land surface displacement in and around the mining areas of the study area, (2) cumulative land surface displacement map during 2021-2024 for the three study areas (e.g., Bageshwar, Pithoragarh and Chamoli). (3) land surface deformation history for a couple of significantly subsiding areas in and around the mines for characterisation of mining-induced subsidence.

References:

Berardino, P., Fornaro, G., Lanari, R., Sansosti, E., 2002. A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms, IEEE Transactions on Geoscience and Remote Sensing, 40 (11), 2375-2383.

Chatterjee, R.S., Singh, K.B., Thapa, S., Kumar, D., 2016. The present status of subsiding land vulnerable to roof collapse in the Jharia Coalfield, India, as obtained from shorter temporal baseline C-band DInSAR by smaller spatial subset unwrapped phase profiling, International Journal of Remote Sensing, 37(1):176-190.

Chatterjee, R.S.,Thapa, S., Singh, K.B., Varunakumar, G., Raju, E.V.R., 2015. Detecting, mapping and monitoring of land subsidence in Jharia Coalfield, Jharkhand, India by spaceborne differential interferometric SAR, GPS and precision levelling techniques, Journal of Earth System Science, 124 (6), 1359-1376.

Ferretti, A., Fumagalli, A., Novali, F., Prati, C., Rocca, F., Rucci, A., 2011. A New Algorithm for Processing Interferometric Data-Stacks: SqueeSAR. , 49(9), 3460-3470.

Ferretti, A., Prati, C., Rocca, F., 2001. Permanent scatterers in SAR interferometry. IEEE Transactions on Geoscience and Remote Sensing, 39(1), 8–20.

Fielding, E.J., Sladen, A., Li, Z., Avouac, J.P., Bürgmann, R., Ryder, I., 2013. Kinematic fault slip evolution source models of the 2008 M7.9 Wenchuan earthquake in China from SAR interferometry, GPS and teleseismic analysis and implications for Longmen Shan tectonics. Geophysical Journal International 194(2), 1138–1166.

Massonnet, D., Rossi, M., Carmona, C., Adragna, F., Peltzer, G., Feigl, K., Rabaute, T., 1993. The displacement field of the Landers earthquake mapped by radar interferometry, Nature 364, 138-142.

Perissin, D., Wang, T., 2012. Repeat-Pass SAR Interferometry with partially coherent targets. IEEE Transactions on Geoscience and Remote Sensing, 50(1), 271–280.

Pranjal, P., Kadiyan, N., Chatterjee, R.S., Kumar, D., Sati, M.S., 2021. Interpreting land subsidence impacts due to groundwater depletion using remote sensing-based GRACE gravity anomaly and DInSAR technique: a study on north-western parts of India. Environmental Earth Sciences, 80 (596).

Werner, C., Wegmuller, U., Strozzi, T., Wiesmann, A., 2003. Interferometric point target analysis for deformation mapping. IEEE International Geoscience and Remote Sensing Symposium. Proceedings (IEEE Cat. No.03CH37477).

1.0 Introduction

Slope stability in open-pit mines located in hilly and mountainous terrain is a matter of critical importance, particularly in geologically sensitive and seismically active regions such as the Himalayas. Ensuring the stability of both mine slopes and waste dumps is essential not only for the safety of workers and equipment but also for maintaining economic viability and minimizing environmental impact.

In these terrains, steep slope angles, highly variable geological conditions, and active tectonics significantly increase the risk of slope failure. Such failures can have far-reaching consequences—including injury or loss of life, damage to equipment, operational delays, and adverse effects on nearby communities and ecosystems.

Given the complexity of Himalayan geology—with its fractured rock masses, fault zones, and high rainfall-induced infiltration—mine slopes that appear stable under dry conditions may become unstable during periods of saturation or seismic activity. Therefore, a detailed and multidisciplinary investigation is essential to understand and mitigate slope stability risks.

This report outlines a comprehensive methodology for investigating mine slope stability using an integrated geological, geotechnical, and geophysical approach. The circulars of Director General of Mines Safety (DGMS) must be followed in the mining opearation.

2.0 Objective

The objective of this investigation is to assess the condition of the rock mass, subsurface characteristics, and potential failure mechanisms that could affect the long-term stability of mine slopes. The methodology has been divided into three major components:

- **Geological Investigation**
- **Geotechnical Investigation**
- **Geophysical Investigation**

3.0 Methodology

3.1 Geological Investigation

The geological investigation aims to establish a thorough understanding of the site's lithology, structural geology, and weathering profile.

3.1.1 Desktop Study

- Compilation and review of existing geological maps, past investigation reports, and remote sensing data, including satellite imagery and aerial photographs.
- Analysis of regional tectonic settings and historical landslide events in the vicinity of the project area.

3.1.2 Field Geological Mapping

- Detailed field mapping of pit slopes and adjacent areas, at scales ranging from 1:500 to 1:2000.
- Identification and documentation of lithological units, contacts, alteration zones, and structural features such as faults, folds, joints, and bedding planes.
- Measurement of discontinuity orientations using compass-clinometers.
- Preparation of geological cross-sections to interpret subsurface conditions.

3.1.3 Rock Mass Classification

- Classification of the exposed rock mass using systems such as:
  - Rock Mass Rating (RMR)
  - Slope Mass Rating (SMR)
  - Q-System for slopes
  - Geological Strength Index (GSI)
- Estimation of rock quality and mechanical behavior for input into slope stability analysis models.

3.1.4 Photogrammetry and Remote Sensing (if applicable)

- UAV-based aerial photography and photogrammetric processing to develop high-resolution Digital Elevation Models (DEMs) and slope face models.
- Extraction of structural features in inaccessible areas using 3D data.

3.2 Geotechnical Investigation

The geotechnical component focuses on determining the mechanical behavior and physical properties of soils and rocks that influence slope stability.

3.2.1 Drilling and Core Logging

- Execution of borehole drilling along critical slope zones and future expansion areas.
- Recovery of continuous core samples for lithological and structural logging.
- Recording parameters such as Rock Quality Designation (RQD), core loss, fracture frequency, and groundwater table depth.

3.2.2 Laboratory Testing

- Testing of representative rock and soil samples as per ASTM, ISRM, and BIS standards.
- Tests include:
  - Moisture content and specific gravity
  - Atterberg limits (for soils)
  - Slake durability and porosity
  - Uniaxial Compressive Strength (UCS)
  - Triaxial compression and direct shear tests
  - Point load index and modulus of elasticity

3.2.3 Rock Discontinuity Survey

- Scanline surveys along exposed rock faces to quantify joint properties: spacing, persistence, roughness, aperture, and infill.
- Stereographic projection and kinematic analysis to determine potential failure modes (e.g., planar, wedge, toppling).

3.3 Geophysical Investigation

Geophysical methods complement geological and geotechnical data by providing insight into subsurface conditions over larger areas and at depth.

3.3.1 Selection of Methods

Appropriate methods to be chosen based on geological setting and depth of investigation:

- **Seismic Refraction** – to delineate weathered zones and estimate P-wave velocities.
- **Electrical Resistivity Tomography (ERT)** – to detect groundwater zones, faults, and lithological variations.
- **Multichannel Analysis of Surface Waves (MASW)** – to determine shear wave velocity profiles for evaluating stiffness and dynamic response.

3.3.2 Field Data Collection

- Establishment of geophysical survey lines both parallel and perpendicular to slope faces.
- Deployment of geophones and electrodes at calculated intervals to achieve desired investigation depths.
- Acquisition of high-resolution data using appropriate field instruments.

3.3.3 Data Processing and Interpretation

- Processing of seismic and resistivity data using advanced software tools (e.g., SeisImager, Res2DInv).
- Correlation with borehole data and geological observations to identify weak zones, moisture pockets, or discontinuities.
- Integration of results into geological cross-sections and 2D/3D geotechnical models.

3.4 Integration and Modeling

- All geological, geotechnical, and geophysical findings are integrated into a unified 3D slope stability model.
- Simulations are performed using advanced software tools (e.g., Slide2, FLAC3D, RS2, Optum, Plaxis, Geo5) to evaluate:
    - Factor of Safety (FoS) under static and dynamic conditions.
    - Behavior of the slope under dry, saturated, and seismic loading.
    - Potential failure modes and deformation patterns.

4.0 Slope Stabilization and Risk Mitigation Measures

Effective slope stabilization and risk mitigation in mining operations, particularly in hilly and seismically active regions like the Himalayas, require a combination of engineering solutions, environmental management, and continuous monitoring.

4.1 The **bench slope angle**, **width of the bench**, **height of the bench**, and **ultimate pit slope** are crucial design parameters that directly influence the stability of mine slopes. Together, these factors determine how safely the pit can be excavated, the risk of slope failure, and the overall integrity of the mine. Here's how each of these factors serves as a controlling element for slope stability

- **Bench slope angle** controls the immediate stability of each bench.
- **Width of the bench** influences load distribution and the safety of the working area.
- **Height of the bench** affects the pressure on the slope and the potential for rockfalls.
- **Ultimate pit slope** defines the overall stability of the mine's sidewalls and is crucial for long-term operations.

In all cases, the interactions between these factors need to be carefully modeled and analyzed using geotechnical and geological data, as well as stability analysis tools, to ensure a safe and economically viable mining operation.

4.1 Drainage Management

- Design and implement surface and subsurface drainage systems to prevent water infiltration, especially during the monsoon season.
- Use of diversion channels, rock drains, and horizontal drains to manage runoff effectively.

4.2 Monitoring and Early Warning Systems

- Install instrumentation such as:
  - Inclinometers for lateral displacement
  - Piezometers for pore water pressure
  - Crack meters and settlement markers
- Adopt advanced remote sensing tools like ground-based radar or satellite InSAR for continuous, real-time monitoring.
- Establish a data-driven early warning system to trigger proactive responses.

4.3 Controlled Blasting Techniques

- Minimize vibration-induced instability by using controlled blasting methods:
  - Short delay blasting
  - Electronic detonators
  - Monitoring of vibration levels
- Optimization of blast patterns to reduce damage to the slope face.

5.0 Conclusion

In complex and geologically active terrains such as the Himalayas, ensuring slope stability is a multifaceted challenge that demands a systematic and interdisciplinary approach. Combining geological insight, geotechnical precision, and geophysical imaging allows for a more comprehensive understanding of slope behavior. By integrating proactive monitoring, smart drainage solutions, and modern blasting practices, mining operations can significantly reduce the risk of slope failures—ensuring both operational efficiency and safety for personnel and nearby communities.

GEOLOGICAL ASSESSMENT AND RECOMMENDATIONS FOR SUSTAINABLE MINING PRACTICES IN BAGESHWAR DISTRICT

On 10.01.2025, the Honorable High Court of Uttarakhand issued an order in relation to Suo Moto Public Interest Litigation number 174/2024, which concerns the developing cracks in houses, fertile lands of villagers and drying up of water resources due to land subsidence in some villages within the district. In compliance with the Court's directive, a multi-organizational committee was established by the Secretary of Industrial Development (Mining), Section-1, through office order no. 77/VII-A-1/2025-09(118)/2024 on 11.01.2025 under the chairmanship of Additional Director, Department of Geology and Mining. The committee, consisting of two members from the Geological Survey of India (GSI), four members from Department of Geology and Mining (DGM), one member from Indian Institute of Remote Sensing (IIRS), and two members from Uttarakhand Landslide Mitigation and Management Centre (ULMMC).

In connection to this, the committee chairman convened a meeting on 16.01.2025 at the DGM Office with the nominated members from various departments to discuss the issue. During the meeting, the chairman briefed the members about the High Court's order and informed that a detailed geological scientific survey report is to be prepared to analyse and study all the forthcoming risk, which may occur due to the mining operations. Based on this report, a revised, more stringent mining policy will be formulated. To meet the objectives set forth, the committee members agreed that creating a multidisciplinary database is crucial to evaluate the forthcoming risk. The committee identified following key components to understand the potential impact of mining operations:

1. **Mining Operation Data**: This includes detailed information about the nature and scope of mining activities, such as the lease boundaries, current excavation areas, and the mining methods adopted. Additionally, historical monitoring data of past mining operations is crucial to understand slope modifications.

2. **Detailed Contour Plan**: A detailed contour plan, paired with cross-sectional profiles, is essential for assessing mine design, topography, and performing in-depth geological investigations of each mine.
3. **High Resolution Satellite Data**: High-resolution Digital Elevation Models (DEMs) and ortho-rectified images of the mines and surrounding areas to generate derivative maps. Temporal high-resolution remote sensing data will be useful in identify changes in slope morphometry and deformation over time in the region due to mining activities.
4. **Geological Data**: Large-scale geological mapping of each mine is essential to understand the local geology and to prepare geological cross-sections. This may also require shallow drilling and geophysical survey at key locations to determine rock overburden contacts and develop accurate geological cross-sections.
5. **Geotechnical Data**: Geotechnical analysis of slope forming material to determine geotechnical properties to perform slope stability analysis to understand the slopes likely to be unstable due to mining activities.
6. **Hydrological Data**: Hydrological data on the availability and condition of water resources, such as groundwater levels, springs, subsurface flow lines, and surface drainage, is vital for assessing how mining operations could impact local water distribution, especially in terms of resource depletion and their potential role in land subsidence.
7. **Thematic Maps**: Creating thematic maps, such as LULC, geomorphology, slope-forming materials (SFM), and slope morphometry maps, will be necessary to develop a comprehensive landslide susceptibility map around the mines, aiding in the assessment of potential hazards in the surrounding areas.
8. **Debris Flow Modelling**: Modelling of potential debris flow may be required to identify areas at risk at downstream. This helps in understanding potential debris flow events that may result from land subsidence or other mining-related disturbances.
9. **Risk Assessment Data**: Finally, predictive models and scenario analyses are needed to assess future risks associated with mining

operations. This includes the likelihood of land subsidence, erosion, and other hazards, enabling the development of proactive strategies to mitigate these risks.

The above database requires procurement, compilation and collaboration of multi-disciplinary departments to conduct a thorough risk assessment and prepare a detailed report. This will assist in developing a revised and more stringent mining policy to reduce the adverse effects of mining activities. On the other hand, the committee was directed to submit the report within one month, as per the office order no. 77/VII-A-1/2025-09(118)/2024 on 11.01.2025, and was later instructed to submit it by 05.02.2025 via letter no. 145/VII-A-1/2025-09(118)/2024. Given the very tight timeline of just 25 days, meeting these objectives was not feasible. Consequently, the committee was asked to proceed for fieldwork via office order no. 6409/भू0खनि0नि0/भू0अनु0/भू0निरी0–बागे0/2024–25 Dated: 16/01/2025 to conduct a preliminary assessment of the individual mines, with a field visit scheduled from 21.01.2025 to 31.01.2025.

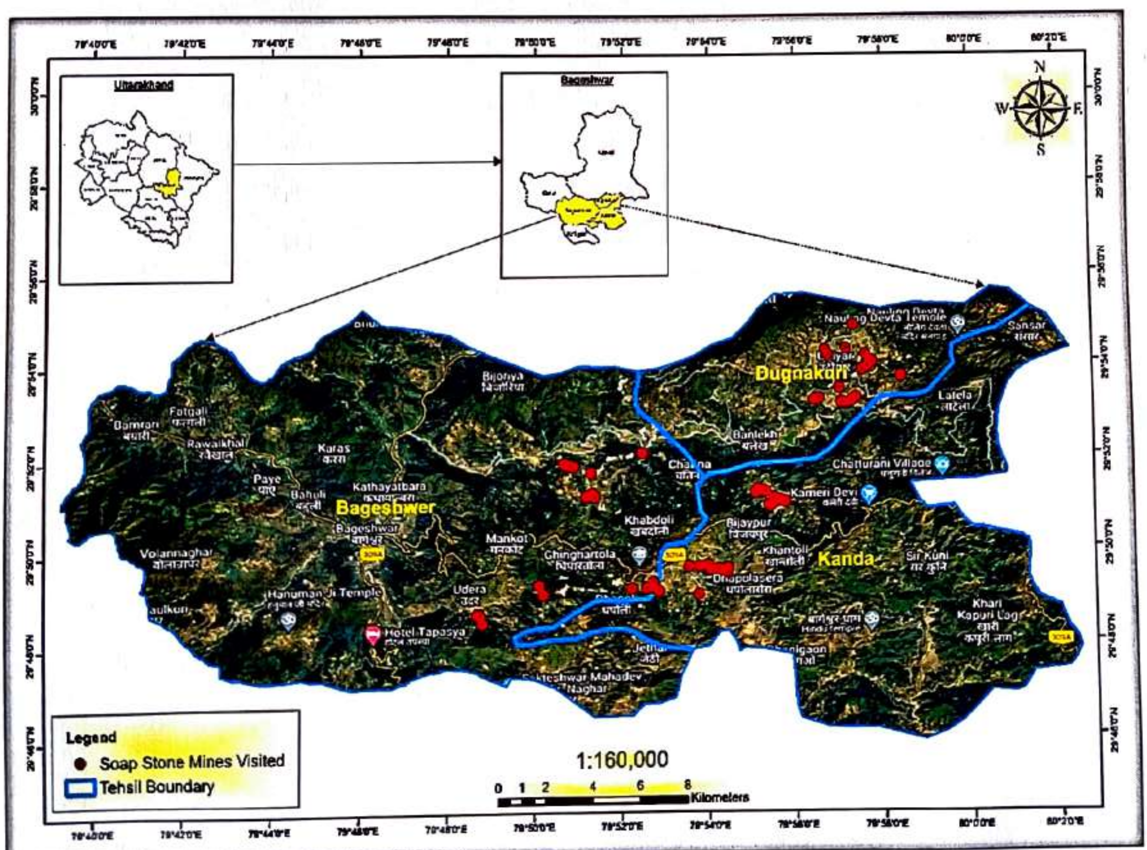


Fig. 1: Map showing the locations of individual mines visited by the committee.

In pursuance to this, the committee members reached Bageshwar on 20.01.2025 and held a meeting with Sh. Ashish Bhatgain (IAS), the District Magistrate of Bageshwar, on 21.01.2025 to discuss about the current situation. During the meeting, it was directed that the committee should also investigate whether the mining activities are being conducted within the designated lease boundaries or not along with other geological observations. The committee carried out field investigation in about 61 mines located in Bageshwar, Kanda and Dugnakuri Tehsils of Bageshwar district in the aforesaid period as shown in Fig. 1 and details of individual mines are given in Annexure-I. During the field visit to the individual mines, the committee documented observations regarding various factors such as the general geology, mining methods used in current excavation, ground deformation features, groundwater conditions, surface drainage, reclamation processes etc. The committee's general observations on each subject matter in view of the more stringent mining policy are summarized below:

1. **Geological Setup:** As per the 1:50K map of GSI, the study area exposes rocks belonging to Berinag and Pithorgarh Formation of Garhwal Groupand Baijnath Formation (Fig. 2). The Pithoragarh Formation of Mesoproterozoic age is comprised of dolomite and slate sequence. Whereas, the Berinag Formation of Mesoproterozoic age is comprised of quartzite and phyllite with basic metavolcanics. The Baijnath Formation of Undifferentiated Proterozoic age occurs as isolated klippe bodies bounded by Baijnath Thrust over the Garhwal Group of rocks. The Baijnath Formation is mainly comprised of biotite gneiss with chlorite schist, quartzite and amphibolite bands. Typically, the contact zone between the Pithoragarh and Berinag Formations contains soapstone and magnesite mineralization, within country rocks. The mineralization occurs as thin to thick lensoidal bodies aligned parallel to the regional foliation of the country rocks. Currently, soapstone is being extracted as the primary mineral, while magnesite is treated as waste or overburden at most of the visited mines, though it may become viable in the future.

2. **Lease Boundary:** To gain a thorough understanding of the potential risks associated with mining activities in the district, acquiring the georeferenced lease boundaries for each mine was crucial. However, since this database was unavailable, fieldwork was carried out using cadastral/khasra maps prepared in the year 1965, over which lease boundaries are marked.

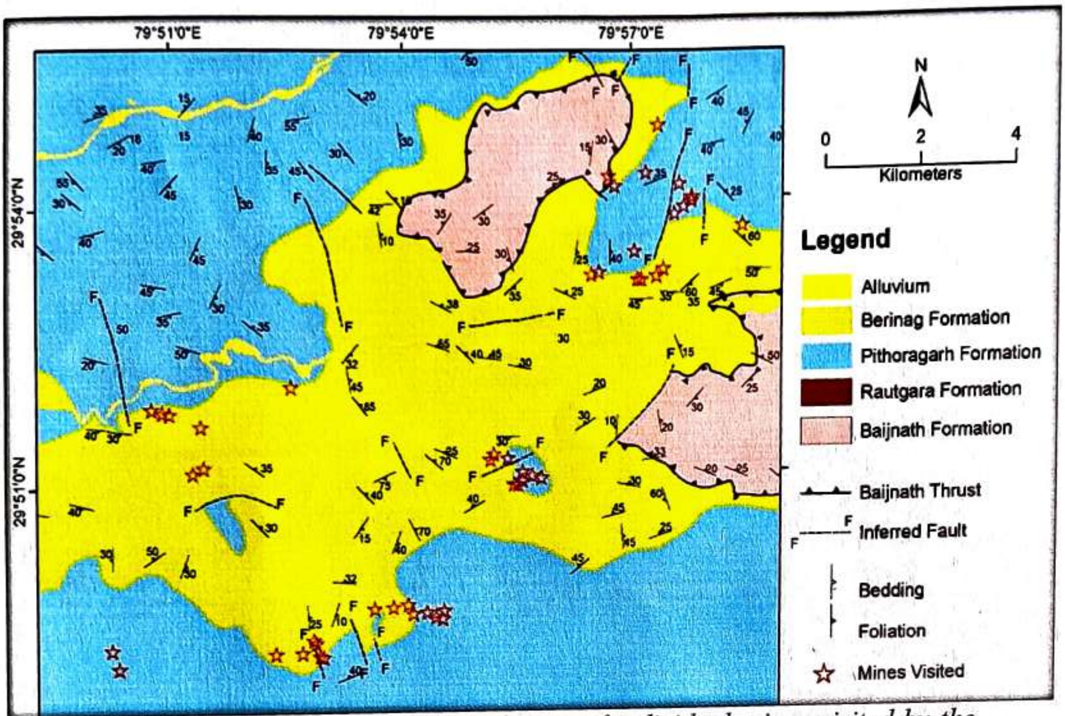


Fig. 2: Geological Map showing the locations of individual mines visited by the committee (Map Source: 1:50K map of GSI).

a. **Risk Elements within Lease area:** As mentioned above, due to the unavailability of georeferenced lease boundaries, it is not possible to accurately determine the area covered by elements at risk within the individual leased blocks. However, field observations indicate that the current lease boundaries encompass critical risk elements such as residential areas, agricultural land, and water resources. The risks to these elements are dynamic, influenced by excavation progress, slope changes, and material properties affecting stability. Moreover, as per the present policy, the responsibility for relocating resident's lies with mine and property owners, which may or may not ensure proper protection.

b. **Unnecessary slope modifications:** In several instances, it was noted during field investigation that areas within the lease boundary were being explored for soapstone by the mine owner, but targeted mineral i.e. soapstone was not found. This exploration method by the mine owners, aimed at detecting the target mineral, led to unnecessary slope modifications. Such unscientific approach by the mine owner is leading to unnecessary slope modifications at several locations, the most notable example can be seen near the Jagnath Mines, as shown in Fig. 3, same observed in Thakur Singh Gariya mines at Surkali Gaon.

Fig. 3: Unwarranted slope modification in the unmineralized rock.

3. **Mining Method Adopted:** The approved mine plan of Harish Chandra Kandpal S/o Trilochan Kandpal Bajina specify a permitted bench height of 3m with a 3m platform with 70° bench slope and overall 45° pit slope. Where's the approved mine plan of Maa Durga Mines and Minerals village Pachar specify a permitted height of 6m with a 8m platform with 68° bench slope and overall 34° pit slope. This variation in bench height and platform is generally being adopted in the majority of the approved mine plans. The committee could not found any supporting documentation indicating that a slope stability analysis was conducted to determine the appropriate bench height required for ensuring a stable mining method. In addition, the following observations were recorded by the committee in field:

a. The committee with the help of Surveyor deployed by DGM, measured the maximum exposed vertical height of the excavated slopes in individual mines. The measured maximum vertical bench height in the presently excavated mine pits is between 7.76m to 29.82m. This indicates that the prescribed bench height was not adhered during excavation, resulting in unplanned slope modifications. Moreover, the maximum vertical exposed depth of the mine was measured to be up to 51.21m, which also raises concerns over the stability of overall pit slope.

b. The committee observed that a large portion of the mines has been backfilled, which makes it challenging to assess the slope modifications over time due to mining activities. As a result, the committee requested regular monitoring data on slope modifications during mine progression from the Mine Manager of the respective mine. However, it was informed that no such records are being maintained. This lack of data creates difficulties in determining the potential risks surrounding the mines.

4. **Ground Deformation features associated with the presently excavated pits:** The committee noted the occurrence of several ground deformation features, including landslides, ground cracks, and sinkholes, linked to various mines. These features can be generally categorized into two groups: within and around the pit and away from the pit, each presenting varying risks to different elements. A detailed summary of the observed ground deformation features is provided below:

   a. **Within and around the pit:** The presence of ground deformation features in the form of ground cracks, debris slides and rockslides were observed within and around the periphery of the presently excavated pits. The details of ground deformation features observed in individual visited mines are discussed below.

   At New Hill Mines, a landslide scar has developed within the mine dump due to toe cutting by the flowing stream

(Fig. 01, Plate-1). This landslide could eventually block the stream, leading to ponding and posing a risk to the downslope area. Retrogressive debris slides have also been observed around the mine's perimeter, resulting from the removal of material for mining, which has been backfilled with additional material (Fig. 02, Plate-1). The stream continues to erode the dump material at the toe, making the slope increasingly vulnerable, and this could result in further loss of land upslope.

At Surendra Singh Boriyal Mines, debris slides have been observed both within the mine's dump material and along its perimeter, mainly due to steep slope cuts at the toe resulting from mining activities (Fig. 03 & 04, Plate-1). In addition, long linear ground cracks, oriented in a NE-SW direction and extending about 50 meters, have been identified (Fig. 05 & 06, Plate-1). During the rainy season, water flowing along these cracks has caused significant gully erosion, reaching depths of up to 2 meters. Over time, this erosion will continue to undercut the slopes, increasing the vulnerability of the surrounding areas to future landslides, same observed in Katiyar and NS corporation mines. Such sections of mines remains a significant risk for further debris slides, posing a potential danger to mine workers.

At the periphery of Kuldeep Singh Bisht Mines, minor landslides (Fig. 07, Plate-1) and sinkholes approximately one foot deep (Fig. 08, Plate-1) have been observed. The mine has been backfilled by simply dumping material, making it difficult to determine the original slope height. The retrogressive nature of the landslides could potentially affect the settlements located upslope. Additionally, the loose backfill material in the mine, lacking any support measures, is vulnerable to landslides over time.

At Nandita Tiwari Mines, debris slides were observed within the dump material at Pit-1 (Fig. 09, Plate-1), and a large debris landslide (Fig. 10, Plate-1) was noted on the periphery of Pit-2. The Pit-3 shows subsidence of approximately 30 meters in length, oriented at 50° towards the northwest, with a depth of 1.5 meters and a separation of 6 cm. This subsidence, beginning at the periphery and progressing uphill, suggests the potential for further expansion, leading to additional subsidence (Fig. 11 & 12, Plate-1). Additionally, the excavated material is being dumped downhill, which could result in the blockage of the stream (nala) at the lower slopes.

At Rajendra Singh Nagarkoti, the presence of ground cracks and debris slide along periphery of the mine was observed due to steep toe cutting by the mining activity (Fig. 13, Plate-1).

At Ram Bharat Mines, subsidence oriented at 60° towards the southeast, with a separation of one foot and varying depths of one to two feet, poses an immediate danger to the pipeline, as any breach could lead to water infiltration into the subsidence zone, increasing the risk of landslides (Fig. 14, Plate-1).

The planar failure in the rock has been observed at Darbaan Singh Parihar Mines (Fig. 15, Plate-1). The slope cut, which is approximately 20 meters high, along with the rock's exposed dip in the same direction, makes the area susceptible to sliding in the near future as well. This highlights the critical need for a thorough understanding of the rock kinematics before disturbing the toe of the rocks.

b. **Away from the pit:** The impacts of mine pits have also been observed away from the mine pits as well. The description of individual mine have been discussed below.

At Gangnath Minerals Mines near Loharkhet Dhapoli Village, debris slides have been observed near the mine's periphery, with ground cracks and subsidence seen about 100 meters upslope. These cracks are clearly visible in Google Earth imagery, with no signs of ground cracks in

May 2019, but visible cracks appearing in January 2025 (Fig. 16, 17, 18 & 19, Plate-1). The ground cracks span approximately 151 meters in length, with subsidence ranging from 2 to 3 meters. Transverse cracks between 1 and 5 meters in length have also been noted in the field. The imagery shows the progressive development of landslides near the pit's periphery and the retrogressive movement of ground cracks upslope, indicating ongoing instability. This soil slide, occurring on agricultural land, exhibits moderate movement and poses an immediate threat due to its retrogressive nature. Additionally, a soil slide on the western flank, measuring 21 meters in length and 44 meters in width, has been observed. The removal of toe support through mining activities, inadequate bench height maintenance, and the dumping of loose debris have made the slope increasingly vulnerable.

Ground cracks with a total cumulative length of 170m were observed on the upslope of Nayal Dhapola Mine. These ground cracks are impacting an area of approximately 51m from the mine's periphery (Fig. 20, Plate-1). These ground cracks are likely to lead a big landslide in near future. The ground subsidence of about 2 meters along with 2-foot separation, having several small longitudinal and transverse cracks were found (Fig. 21 & 22, Plate-1). The mine has been backfilled by dumping loose waste material, making it impossible to generate a slope profile to assess the causative factors and their potential long-term impact. Additionally, the retrogressive nature of the landslide suggests that it will soon affect the agricultural land upslope, leading to further subsidence in the northern direction.

The field observations reveal that the overburden material from the Mangal Singh Dhami mine (located in upslope) extends to the Dhaulinag mine (located downslope). Google Earth imagery shows that the Dhaulinag mine did not exist in August 2014 (Fig. 23, Plate-1). However, after the mine developed within a natural drainage, mining activities triggered a landslide in March, 2019 due to toe cutting (Fig. 24, Plate-1). By February 2021, the imagery shows the landslide had retrogressed to the Mangal Singh Dhami mine, causing the overburden material to flow along the landslide zone and merge with the downslope mine (Fig. 25, Plate-1). This illustrates how mining activities in the region contribute to the loss of agricultural lands and potential risk to the mine workers.

5. **Hydrological Condition:** The committee conducted an assessment of the hydrological conditions at the visited mines in terms of condition of groundwater and surface drainage. The observations on each aspects are as follows:

   a. **Groundwater condition:** It was observed that in most of the mines, seepage occurs at relatively shallow depths, where the soapstone is encountered. Soapstone, being a metamorphic rock composed mainly of talc, chlorite, and other minerals, typically exhibits low permeability. This low permeability helps prevent the movement of groundwater, allowing soapstone-bearing strata to function as an aquiclude. However, this layer is punctured in most of the mines resulting to seepage and leading to water accumulation in the excavated pits and a continuous discharge of groundwater. This ongoing discharge can potentially lead to the depletion of local groundwater levels. The Himalayan region is known for having perched water tables at different levels, and without a clear understanding of their relative positions, it is challenging to assess the long-term effects on water availability and resource sustainability.

   b. **Surface Drainage:** The committee observed that the unplanned dumping of overburden material from the mine into the surface drainage system is causing blockages and diversions of nala courses. This improper disposal not only disrupts the natural flow of water but also leads to the contamination of water with mine material, potentially

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affecting water quality and the surrounding environment. In the event of a cloudburst, the blocked drainage system may exacerbate flooding risks, leading to severe damage to downslope areas.

6. **Reclamation methods adopted:** The committee assessed a few reclaimed land areas at different localities. In these locations, the land was reshaped and contoured to blend with the surrounding landscape through activities such as filling pits, grading slopes, and creating terraces. However, the committee found no evidence of studies or methodologies aimed at ensuring the long-term slope stability of the reclaimed land, nor any measures in place to provide additional support against gravitational forces. While no ground deformation features were observed in the reclaimed land, the committee recommends that the reclamation efforts be reviewed by the relevant authorities to ensure they comply with established policies. In the future, the instability of these reclaimed areas may potentially lead to landslide or debris flows due to the dynamic geological and climatic conditions in the region, which may pose significant risk to areas downslope.

CONCLUSIONS: In conclusion, the observed ground deformations, including debris slides, ground cracks, subsidence, and rockslides, across multiple mines highlight significant risks to both the mine workers and the surrounding infrastructure. The steep excavation practices, lack of adequate slope support, and ongoing mining activities have contributed to these instabilities, with many sites showing signs of retrogressive movement and further land loss. The presence of water sources, such as streams and perennial nala, exacerbates the potential for landslides and erosion, posing an increasing threat to mine workers and nearby settlements. The field inspection of 61 mines across the Bageshwar, Kanda, and Dugnakuri Tehsils in Bageshwar district resulted in the following general observations:

1. In most of the mines, the magnesite is currently considered waste, additional studies on improved extraction methods or alternative uses of the mineral may potentially enhance its economic value in the future.

2. The current lease boundaries often encompass residential areas, agricultural lands, and water sources, presenting significant risk elements.
3. Mining operations have not adhered to prescribed bench heights, leading to unplanned slope modifications.
4. Mining operations have resulted in water seepage and drainage disruptions, which may contribute to groundwater depletion and contamination.
5. The committee observed that reclamation efforts being made might lack a, long-term sustainability plan, particularly for preventing slope instability and debris flow.
6. The lack of systematic monitoring and data collection at the mines complicates the assessment of ongoing and future risks.

RECOMMENDATIONS: The occurrence of landslides and ground cracks within and around the mine area are clear indicators of unsustainable mining practices, leading to slope instability. The committee emphasizes the need for a more thorough and scientifically grounded approach to mining activities in the region, especially in light of the unique geological and climatic conditions of the Himalayan belt. Based on field observations, the committee offers the following recommendations for a more stringent mining policy:

1. A georeferenced database of the lease boundaries for each mine should be created to understand a comprehensive risks related to mining in the district.
2. Lease areas that include risk factors such as settlements, agricultural land, and water sources may be reassessed. A resettlement framework may be developed, emphasizing safety and sustainability.
3. Given the dynamic risks to critical elements like homes, agricultural land, and water sources influenced by excavation progress, slope changes, and material properties affecting stability, it is recommended to adopt more sustainable mining practices that can manage these changes to prevent forthcoming risks.
4. Comprehensive geo-exploration and volumetric analysis should be carried out to evaluate mineral continuity in both currently

allocated and future lease areas. This will ensure that minerals are extracted from economically viable sites and help prevent unnecessary slope modifications.

5. A comprehensive slope stability analysis is recommended to determine the appropriate bench height for safe mining and ensure proper on-site monitoring.
6. Regular instrumental slope monitoring and detailed record-keeping of slope modifications during mining activities are essential for effective risk assessment and improved management of mining operations.
7. Aquifer mapping may be conducted to identify perched water tables and evaluate the long-term impact of mining on groundwater levels and resource sustainability.
8. Overburden material should be disposed of away from drainage systems, and these systems must be maintained to prevent blockages and reduce the risk of flooding, particularly during cloudbursts.
9. Reclamation efforts should be reviewed to ensure policy compliance and long-term stability, with special attention to the harsh climatic conditions of the Himalayan region. Measures to enhance slope stability and mitigate risks such as debris flow, landslides, and erosion should also be implemented.
10. The future economic viability of magnesite as a resource should also be considered when granting lease blocks, and this factor may be incorporated into the policy framework.
11. The mining policies or plans that have been implemented in other states for open-cast mining can be studied to develop a more stringent policy.

The recommendations provided are based on general observations and may not fully align with or conflict with existing mining policies. They are intended to guide improvements in mining practices. However, their applicability may vary depending on specific local conditions, legal frameworks, and operational constraints. These recommendations should be thoroughly reviewed and adjusted by relevant authorities to consider the unique geological, environmental, and socio-economic conditions of the region, particularly in the tectonically active and environmentally sensitive Himalayan belt.

Hills Mines: Field photographs showing debris slides in the dump material and around the phery of the mine

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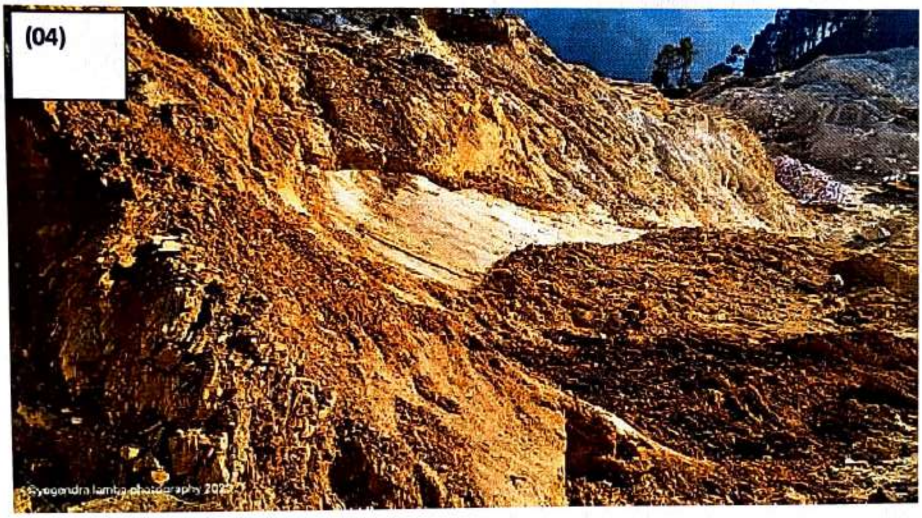
PLATE-1(cont.)

Surendra Singh Boriyal Mines: Field photographs showing debris slides within and around the periphery of the mine along with ground cracks and gully erosion extending upslope.



Kuldeep Singh Bhist Mines: Field photographs showing minor debris slides and sink holes at the crown portion of the backfill material.

ditaTiwari Mines: Field photographs showing debris slides and ground cracks around the iphery of the mine.

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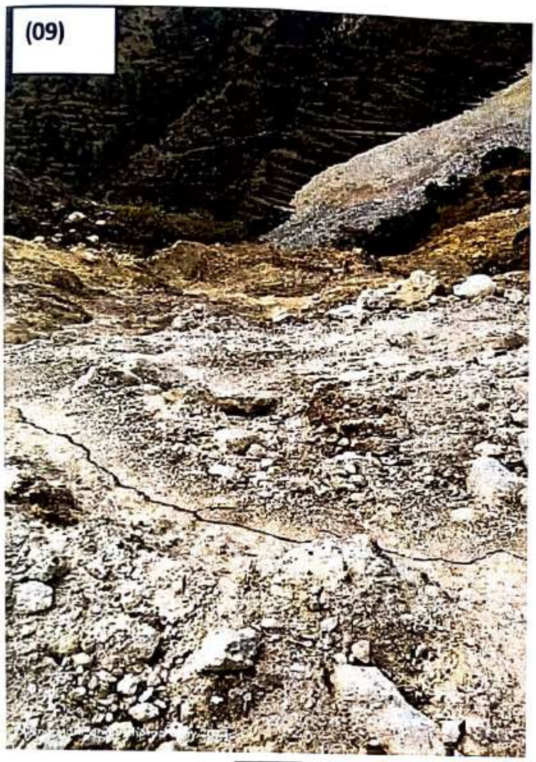

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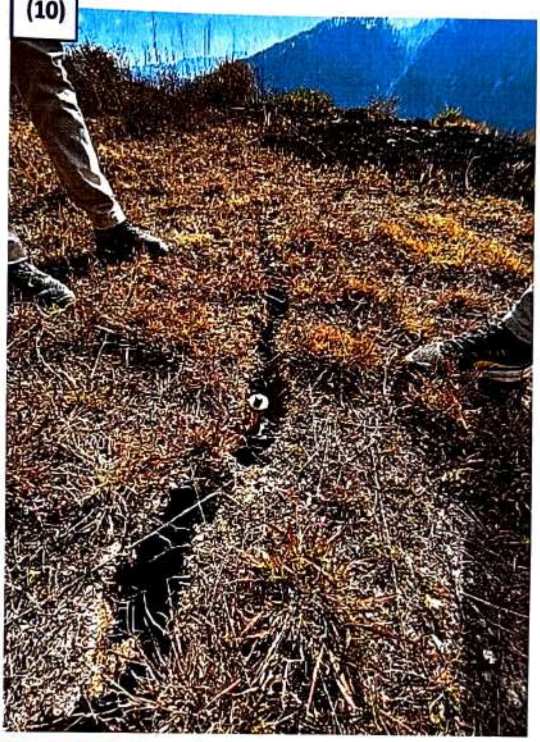

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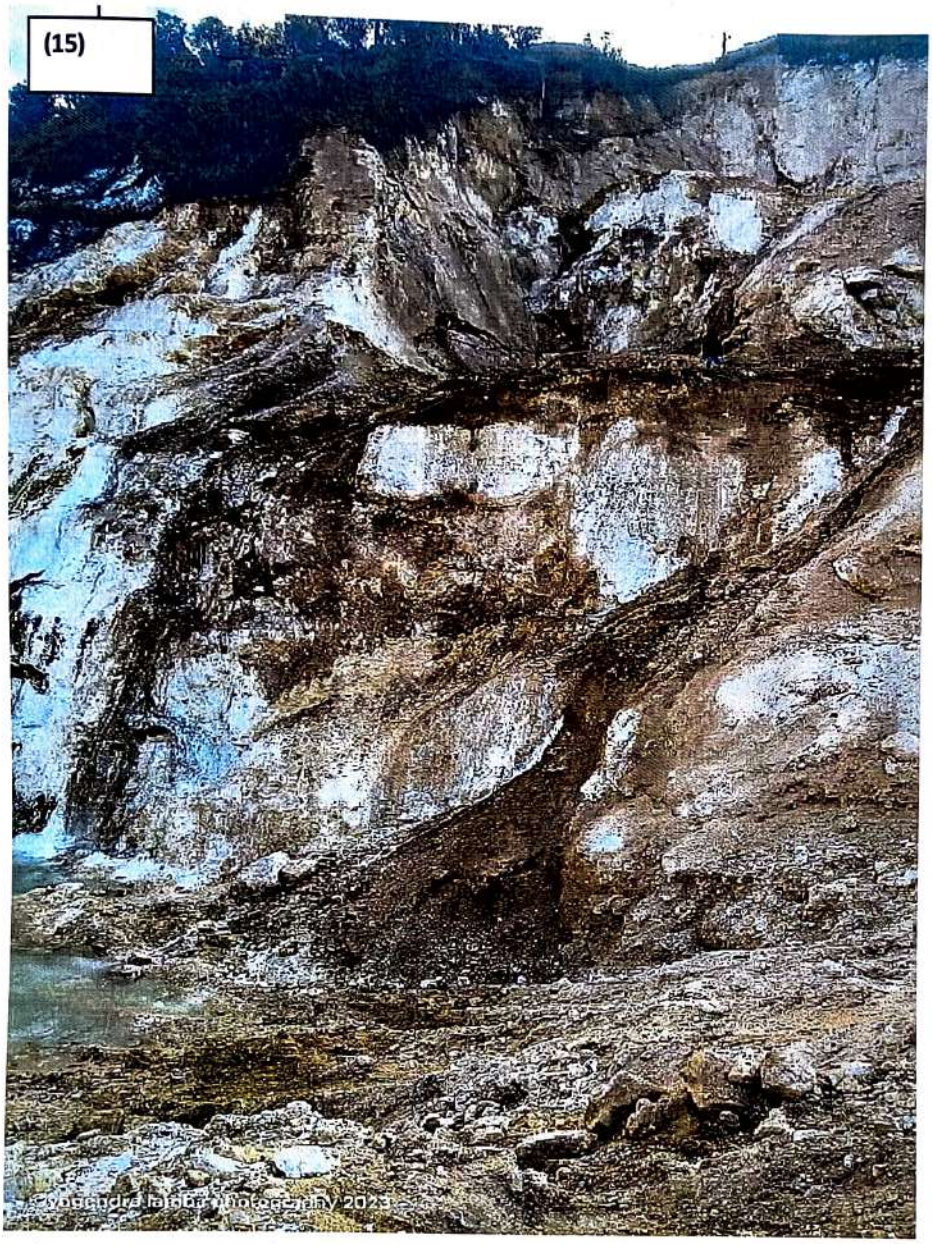
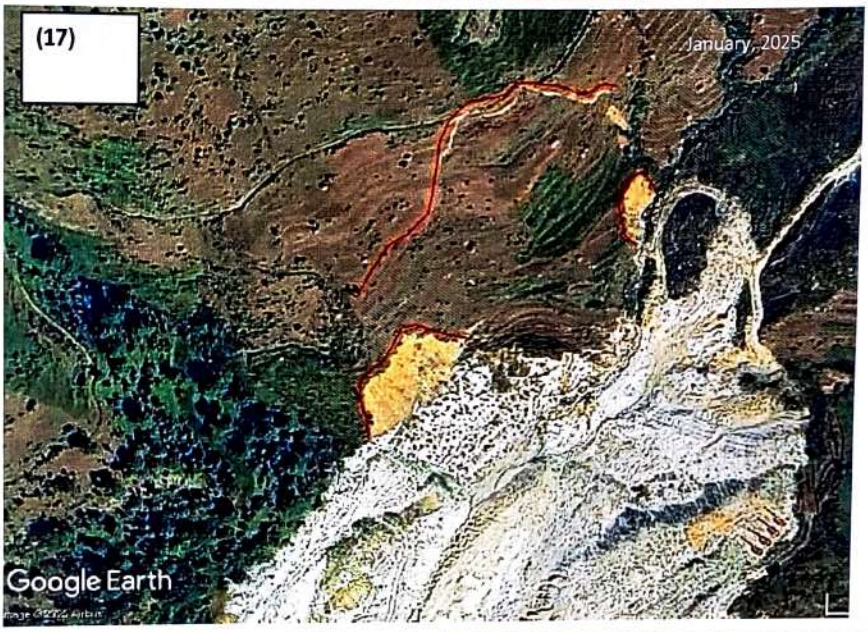
Debris slide at the periphery of **Rejendra Singh Nagarkoti Mines**

Ground Cracks along periphery of Ram **Bharat Mines**

Planner failure in **Darbaan Singh Parihar Mines**



...ath Minerals Mine: Google Earth imagery and field photographs showing development ...ound cracks and debris slides around and away from the mine.

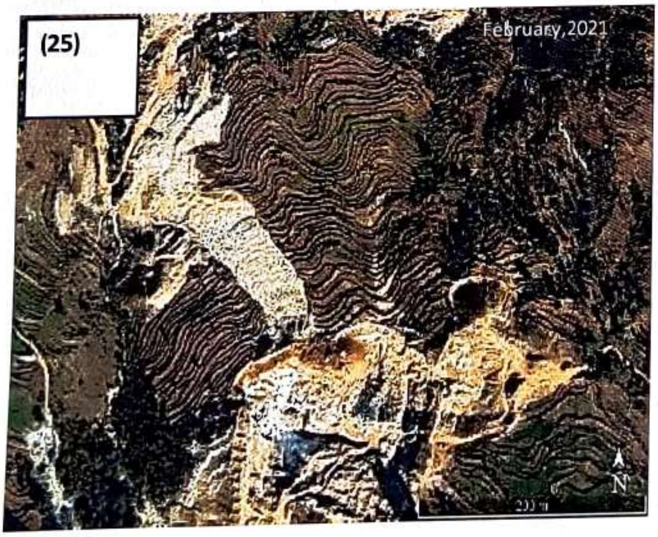


hapola Mines: Field photographs showing development of ground cracks and associated ence away from the mine.

PLATE-1(cont.)

हरितामा रावत

ulinag Mines: Google Earth images revealing the gradual alterations in the landscape and reduction of agricultural land caused by landslides triggered by mining operations.



ure -1

of the mines visited –

No.	Name	Lease Area (In Ha)	Village	Tehsil	Latitude	Longitude
1	Naveen Kumar S/O Gopal Ram	4.156	Bhairuchaubatta	Bageshwar	29.86326328	79.84831526
2	Jai Shree Ganganath Minerals	3.834	Bhairuchaubatta	Bageshwar	29.85238866	79.85312125
3	Naveen Kumar S/O Gopal Ram	4.868	Bhairuchaubatta	Bageshwar	29.86422027	79.84459194
4	Shiv Shakti Mines and Minerals	4.996	Biladi	Bageshwar	29.8608675	79.85496926
5	Khadak Singh Dafauti	4.944	Chauni Chamarthal	Bageshwar	29.8170578	79.83666993
6	Khimuli Devi	13.355	Dhunga Patli	Bageshwar	29.81018092	79.81124929
7	Rudra Mines	4.292	Dunga	Bageshwar	29.80699764	79.81347202
8	Maa Chandika Mines	7.971	Dunga	Bageshwar	29.80997021	79.81247335
9	Rajesh Verma	13.167	Kholiya Gaon	Bageshwar	29.86786916	79.87458076
10	M/S Parvatiya Mines	52.340	Khunoli	Bageshwar	29.85204188	79.85649901
11	Agari Minerals	2.469	Kumaldev(Bhairuchaubatta)	Bageshwar	29.8635226	79.84688792
12	Kantilal Shah	8.490	Nayal	Bageshwar	29.82048873	79.83521941
13	Manish Nand Kishore Aggarwal and Vimal Kumar Aggarwal	10.841	Nayal Dhapola	Bageshwar	29.8533754	79.85546996
14	Inder Lal. Firm Name- Balaji Minerals	4.168	Chakpahruda	Dugnakuri	29.89738249	79.95902371
15	Parth Minerals	10.276	Gumti	Dugnakuri	29.88667925	79.94064604
16	Diwan Singh Papola. Firm Name- M/S Shikhar Soapstone	2.990	Kafli & Papoli	Dugnakuri	29.90454323	79.94473919
17	Ramesh Singh Chauhan, Nauling Minerals	4.994	Kidai	Dugnakuri	29.88562785	79.9508663
18	Nauling Minerals Laxman Singh	1.500	Kidai	Dugnakuri	29.89075986	79.95023526
19	New Hills Mines & Minerals	10.210	Kidai Chak Dhamigaon	Dugnakuri	29.88554409	79.9516125
20	Praveen Singh Papola	10.007	Kirai Chak Dhamigaon	Dugnakuri	29.88612816	79.95496365
21	M/S NS Corporation	86.519	Kiroli	Dugnakuri	29.90507247	79.95286012
22	Surendra Singh Bhauriyal & Govind Singh Dhami	2.469	Mhauli	Dugnakuri	29.89495061	79.9739127
23	M/S Amba Mines & Minerals	2.070	Oliyagaon	Dugnakuri	29.88710278	79.9423828
24	Thakur Singh Gadia (Maa Durga Mines & Minerals)	12.360	Pachar	Dugnakuri	29.8873804	79.95650029

	[illegible]iwan Singh Papola. Firm Name- M/S Shikhar Soapstone	2.413	Papoli Lagga, Kafli & Udiyar	Dugnakuri	29.90273145	79.94599278
[illegible]6	Balwant Singh Bhauryal	4.980	Raikholagaon	Dugnakuri	29.90033787	79.96290668
27	Mahesh Singh Bhauryal S/O Balwant Singh Bhauryal	5.800	Sirala Gaon	Dugnakuri	29.89867876	79.96110478
28	M/S Katiyar Mining	139.372	Surkali Gaon	Dugnakuri	29.90286819	79.96013737
29	Thakur Singh Gariya. Firm Name- M/S Garia Mining Cor.	2.330	Surkali Gaon	Dugnakuri	29.91366873	79.95559881
30	M/S KB Mines & Minerals	4.720	Tharaejiar	Dugnakuri	29.89971651	79.96279107
31	Harunath Mines	6.507	Adhyali	Kanda	29.84888611	79.92323309
32	Bhuvan Joshi S/O Chandra Mani Joshi	8.843	Bajina	Kanda	29.82736704	79.89971046
33	Dinesh Singh Parihar S/O Sheetal Singh Parihar	4.941	Bajina	Kanda	29.82597314	79.90386195
34	Jagnath Minerals	3.840	Bakhet	Kanda	29.82578181	79.90085634
35	Ganga Prasad Pandey	0.790	Banstoli	Kanda	29.85443242	79.91887549
36	Rajendra Singh Nagarkoti S/O Shri Bahadur Singh Nagarkoti, Sh.Sanjeev Kumar S/O Sh. Suraj Bhan	4.933	Banstoli Rajoli	Kanda	29.85346317	79.91811929
37	Sher Singh Dhapola	1.450	Dhapolasera	Kanda	29.82403625	79.91387593
38	Shri Ram Bharat Mines	10.320	Dhapoli	Kanda	29.81902743	79.87059556
39	Stuti Minerals Pvt.Ltd.	4.840	Dhapti	Kanda	29.84518188	79.93169999
40	Fateh Singh Parihar	4.491	Ganduwa Sirmoli	Kanda	29.85365936	79.92187673
41	Ummed Singh Kalakoti	4.790	Ganduwa Sirmoli	Kanda	29.8487473	79.92410492
42	Dhaulinag Mines & Minerals	3.784	Ganduwa Sirmoli	Kanda	29.84947639	79.92507359
43	Mahesh Chandra Pant. Firm Name- M/S Sirmoli Mines Pvt.Ltd.	4.590	Ganduwa Sirmoli	Kanda	29.85108871	79.92509833
44	Darban Singh Parihar	- 5.800	Ganduwa Sirmoli	Kanda	29.84990862	79.92920996
45	Harish Chandra Kandpal and Kailash Chandra Bhatt	3.687	Jagthali	Kanda	29.82506859	79.90586094
46	Jai Dholinag Mines. Firm Name- Jai Dholinag Enterprises	4.270	Jaspur	Kanda	29.84673164	79.92595743
47	Dev Bhoomi Mines (Partner Mr. Ramesh Chandra Pandey, Mr. Umesh Chandra Pandey etc.)	15.313	Kabhata	Kanda	29.82095516	79.92691149

	Kuldeep Singh Bisht	4.810	KandeKanyal	Kanda	29.82678956	79.89233919
	Girish Chandra Petsali	2.180	KandeKanyal	Kanda	29.81690726	79.8962898
	Ganganath Minerals	4.762	Loharkhet & Dhapoli	Kanda	29.82134772	79.8788501
	Umesh Chandra Pandey	4.822	PaliChak Titoli	Kanda	29.82618457	79.90758718
52	Pooran Singh Majila	11.233	Pangchaura	Kanda	29.81886923	79.88385901
53	Ashok Pal	4.752	Sasola	Kanda	29.83650496	79.90411132
54	Deep Chandra Verma	8.498	Sunar Gaon, KandeKnyal	Kanda	29.82697449	79.89649511
55	Nandita Tiwari (Nitin Tiwari) Firm Name- M/S Kumaon Mines	49.700	Sunar Gaon, KandeKnyal	Kanda	29.82649651	79.89624796
56	Prakash Singh Dhapola and Hem Chandra Upreti. Jai Shree Gangnath Minerals	4.191	Talla Dhapoli	Kanda	29.81903979	79.87642433
57	Nandita Tiwari (Nitin Tiwari) Firm Name- M/S Kumaon Mines	23.097	Tharp	Kanda	29.82080942	79.87939217
58	Govind Singh Rautela	4.620	Titoli	Kanda	29.8257704	79.91250916
59	Geeta Bhauriyal	4.698	Titoli	Kanda	29.82404065	79.9090032
60	Pankaj Bhatt	4.310	Toli Jagthali	Kanda	29.8246561	79.90726818
61	Ummed Singh Kalaloti	3.080	Vijaypur	Kanda	29.84714504	79.92369613

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Asst. Geologist
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Ravi Singh Negi
Asst. Geologist
(D.G.M, Tehri)

Haritabh Rana
Asst. Geologist, (G.S.I)
(Agreeing with the attached Dissent note)

Yogendra Singh
Sr. Geologist, (G.S.I)
(Agreeing with the attached Dissent Note)

Lekh Raj
Dy Director/Geologist
(D.G.M. pithoragarh)

Anil Kumar
Add. Director/ Chairman
(D.G.M, Dehradun)

Dissent Note on the report "Geological Assessment and Recommendations for Sustainable Mining Practices In Bageshwar District"

The undersigned committee members agree with the above-mentioned report with the inclusion of following point:

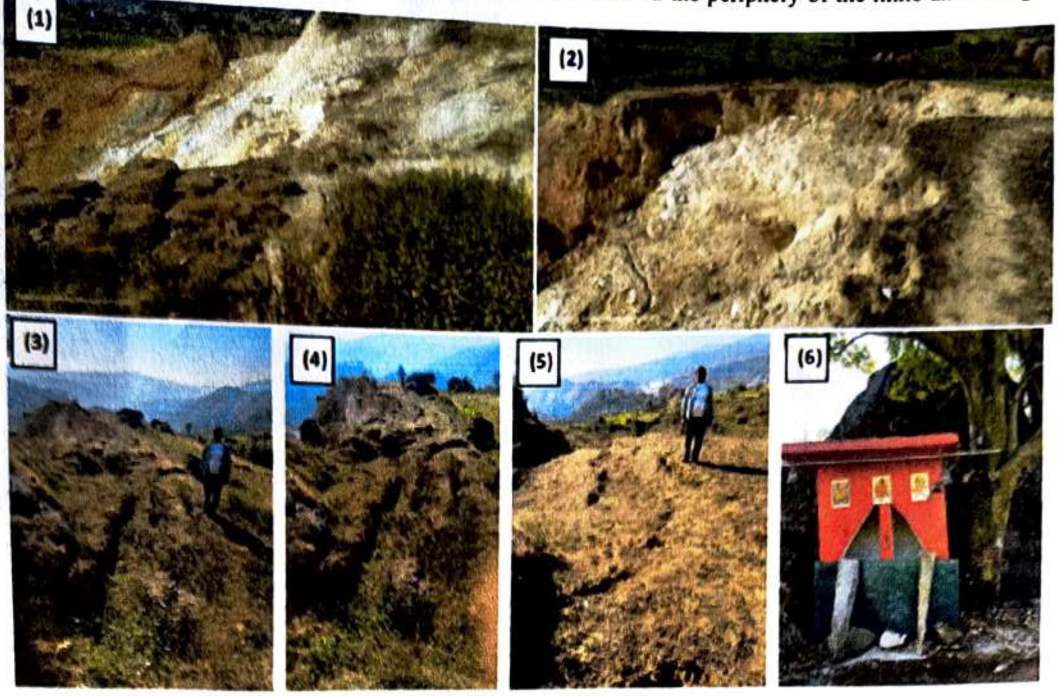
The examples mentioned under **4. Ground Deformation features associated with the presently excavated pits; Subheading a. Within and around the pit** following additional points are suggested:

1. At Katiyar Mines, the steep excavation of materials is causing debris slides around the edges of the mine (Photograph 1 & 2). Currently, ground cracks, measuring 30m in length and oriented at 210° towards the southeast, along with associated subsidence, are appearing near the mine's edge in agricultural land (Photograph 3 & 5). A perennial stream (Latera Gad) flows upslope of these cracks and could potentially trigger a large landslide, posing a significant risk to mine workers in the near future. The subsidence from these cracks has also caused tilting of a nearby temple (Photograph 6). The occurrence of such debris slides at the mine's perimeter, along with their retrogressive movement, emphasizes the urgent need for a thorough understanding of sustainable vertical slope cuts to prevent further incidents and the loss of land near the mine.

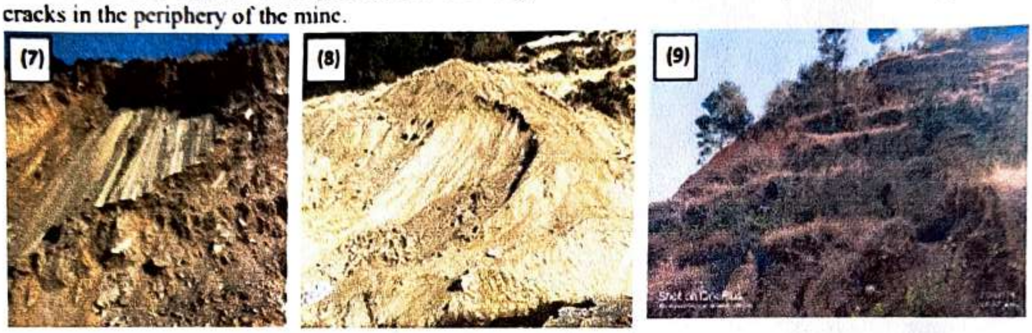
2. At Naveen Kumar Mines, east-west oriented ground cracks with subsidence, showing an opening of 0.3 to 0.5 meters and a depth of 1.5 meters, have been noted (Photograph 6). A "Baraat ghar" built at the mine's edge has tilted and is at risk of collapsing, posing a danger to workers working downhill. Additionally, debris slides have been observed within the mine's dump material (Photograph. 7 & 8), and ongoing excavations below these dumps present a risk to workers in the area. The presence of debris slides at both the mine's perimeter and within the dump material highlights the critical need for a comprehensive understanding of sustainable vertical slope cuts to prevent further incidents and protect nearby land from loss.

3. At NS Mines, the presence of ground cracks (Photograph 16) and debris slide (Photograph 17) in the loose dump material was observed due to toe cutting for mining activity. This type of the mine method along steep cuts continues to pose a risk of further debris slides, presenting a potential danger to mine workers.

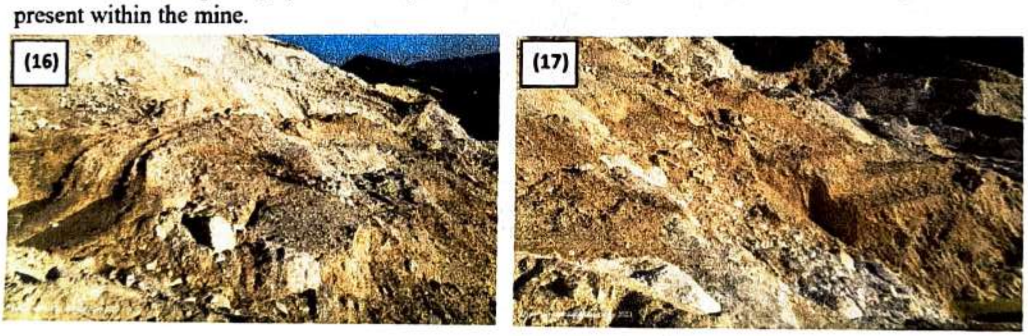
Katiyar Mines: Field photographs showing debris slides around the periphery of the mine and tilting in the temple.



Naveen Kumar Mines: Field photographs showing debris slides in the dump material and ground cracks in the periphery of the mine.



NS Mines: Field photographs showing debris slides and ground cracks in the dump material present within the mine.



Field Photographs of Katiyar, Naveen Kumar Mines and NS Mines.

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