Shallow depth mines: Are these more stable & safe?? Ponder

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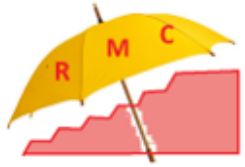
Director



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Commonly prevailing mis-conception

- A shallow mine:
  - so no effect of stress/ strain
  - At 5060m depth, almost no load
- So no need to have scientific design, monitoring, etc.
- But the ground reality is just otherwise:
  - Rock strength reduced to that of soil/ clay
  - Safety scenario : Some shallow mines: Let’s go through Print media reportings only
  - Cost of Accident
  - Remediation
  - Way forward

Dimension Stone Pit collapsed at 17m depth fatalities 7 -on 12th Aug 2021

भीलवाड़ा में खदान धंसने से 7 की मौत: पत्थर की खदान ढहने से 3 महिला समेत 7 मजदूर दब गए थे, 50 फीट गहराई में 11 घंटे तक चला रेस्क्यू, सभी शव निकाले

भीलवाड़ा 3 महीने पहले

वीडियो

दैनिक भास्कर

सीज खदान से हो रहा था खनन

Iron ore mine – even at surface, one bench collapsed trapping 3 people in dry season

NMDC के एसपी-3 स्क्रीनिंग प्लांट में चट्टान धंसी, 4 मजदूर मलबे के नीचे दब गए, 3 मजदूरों की हुई मौत

काम करने के दौरान करीब 3 से 4 बजे के बीच चट्टान धंस गई। जिससे पूरा मलबा नीचे मौजूद मजदूर और पोकलेन पर आ गिरा।

By **Industrial Punch** - 27 February 2024

Granite Mine, Pali, Rajasthan

- Granite Mine: strongest rock
- Joints- Water percolation,
- Weathered
- No proper design followed

ऊपर ड्रिलिंग, 50 फीट से गिरी 25 टन की चट्टान; 3 की मौत

पाली में दहला देने वाली घटना

पाली | साकदड़ा में बुधवार सुबह ग्रेनाइट खदान में 3 श्रमिकों की मौत हो गई, 3 घायल हो गए। इनमें एक की हालत गंभीर है। घटना पन्ना मिश्री ग्रेनाइट माइंस पर हुई। वहां सुबह ऊपर पत्थर तोड़ने के लिए ड्रिलिंग हो रही थी, नीचे श्रमिक काम कर रहे थे। कंपन से खदान के ऊपर की बड़ी चट्टान खिसकी और 50 फीट नीचे कार्यरत 6 श्रमिकों पर आ गिरी। चट्टान 25 टन यानी 25,000 किलो वजनी होने से देवगढ़ क्षेत्र के बोरदी निवासी मोहनलाल (20) पुत्र देवा मीणा, हेमराज (19) पुत्र कन्हैयालाल मीणा व धारीवाद निवासी महावीर (22) पुत्र शंभूराम मीणा की मौके पर ही मौत हो गई। दो घंटे मशक्कत के बाद इनके शव निकल पाए। गंभीर घायल शांतिलाल (30) पुत्र देवा मीणा को जोधपुर रेफर किया गया। अन्य 2 श्रमिकों श्रवण व ईश्वर को हल्की चोटें आईं, जिन्हें प्राथमिक उपचार के बाद छुट्टी दे दी गई। संभागीय आयुक्त प्रतिभा सिंह ने टीम मौके पर भेजी, जांच कमेटी भी गठित की है। बताया गया कि ये मजदूर 15 दिन पहले ही यहां काम करने आए थे।

यहां से गिरा पत्थर

6 लोग दबे पत्थर के नीचे

P M Granite mine: 40m deep (Pali, Feb 2024)

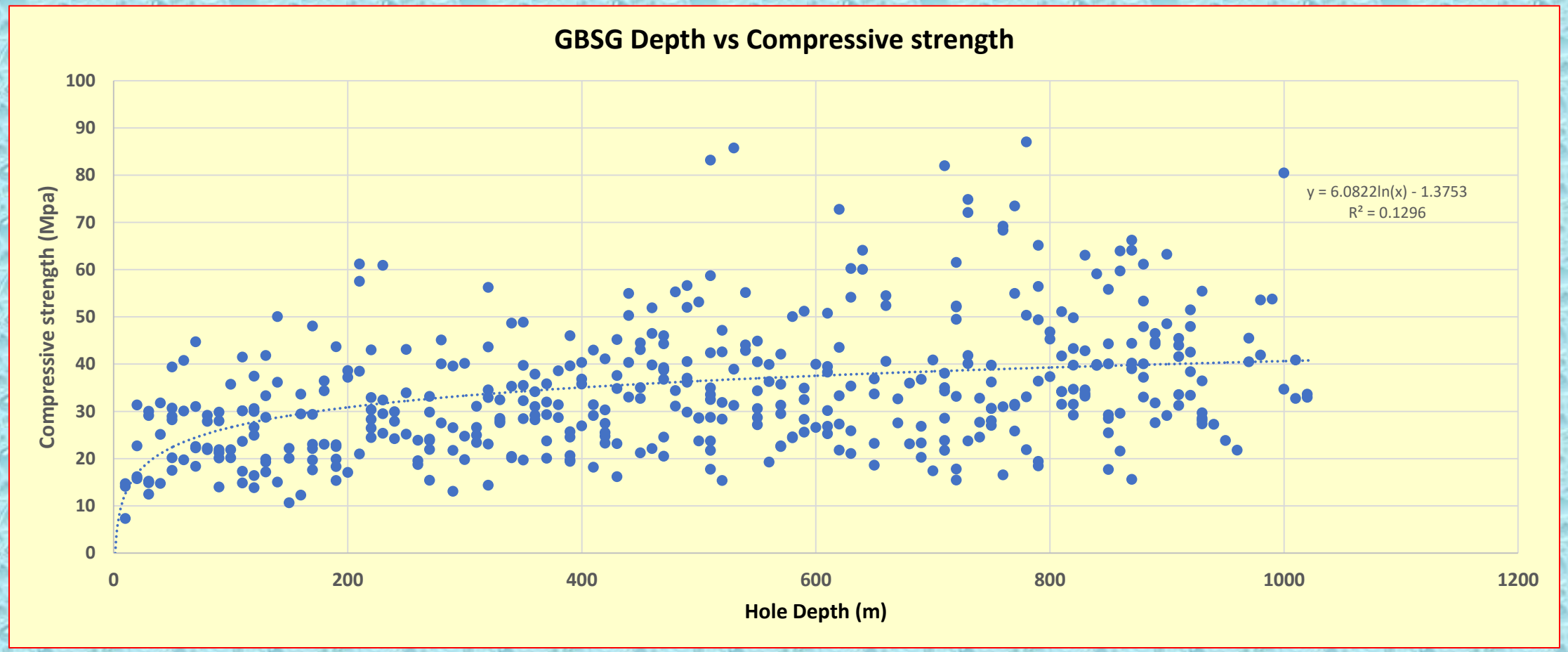
In fact shallow workings are more prone for failure

- Shallower pits: it is the degree of weathering of the rock stuff that makes a slope conducive for failure
- Beyond 300-400m, role of stress comes into action

Shallow depth means:

- Rock mass- degraded
- UCS degraded from MPa to KPa, RMR 50-60 to <20
- Discontinuities are more weathered, in-filling work like lubricant
- More weakened
- Amphibolite of 120MPa crumbles in hand, phyllite crumbles in hand, hematite crumbles in hand
- Poor throw of blasting in upper 30m- which further exponentially increases back break
- Profound effect of rain water- running water
- Weathered rocks when get wet, decomposed material works as lubricant and facilitate sliding

Variation of Compressive strength with depth



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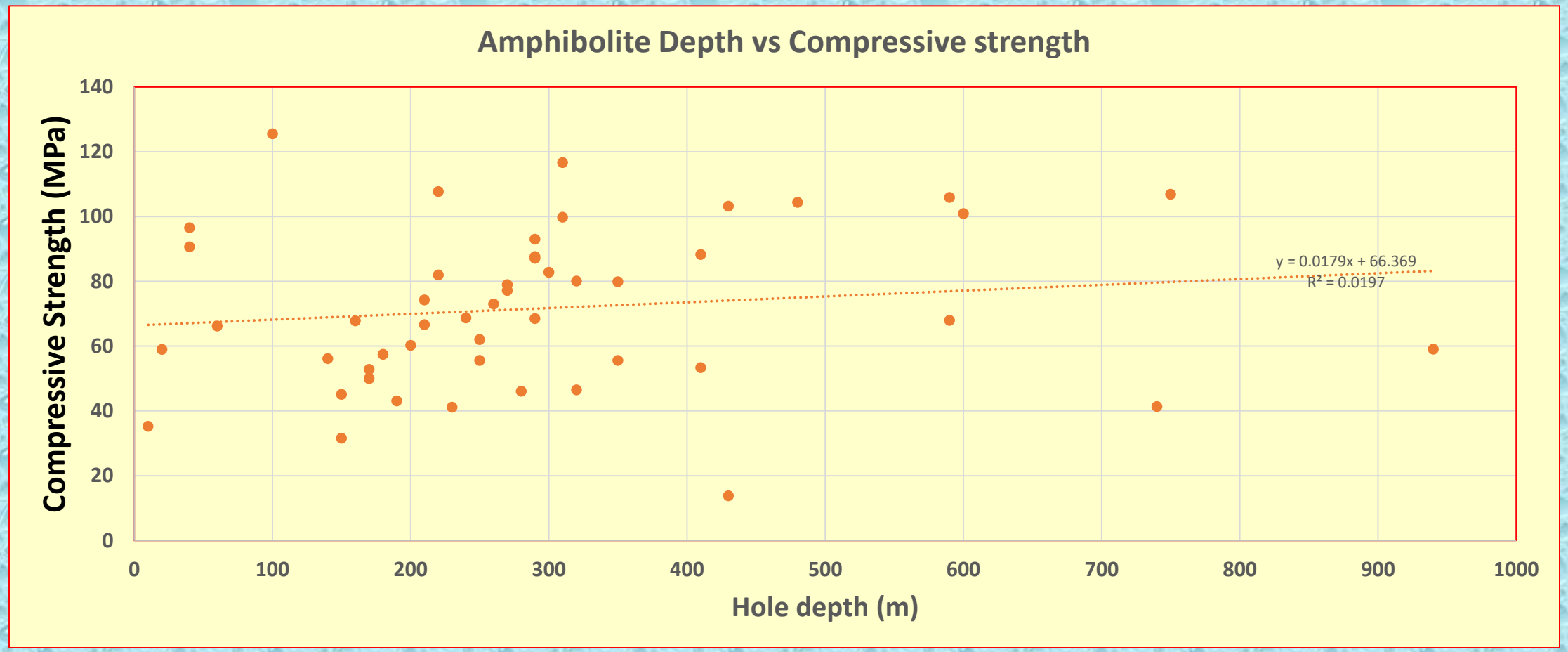
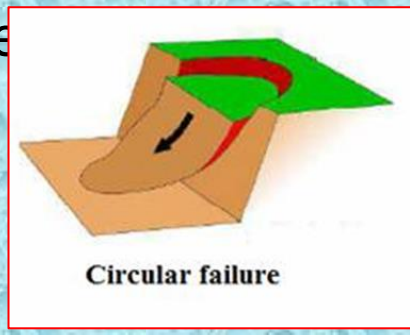


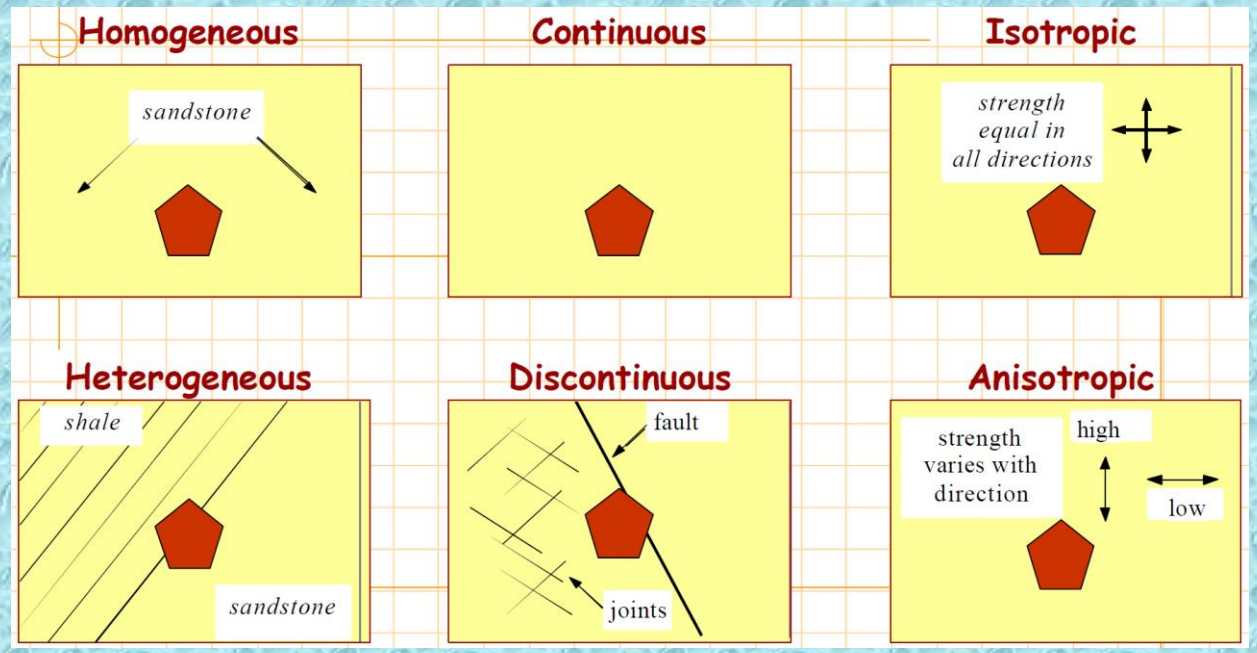
In shallow workings

- Rocks are highly weathered so their behaviour is towards soil or clayey substance rather than rocks-
  - Rock strength < 5MPa, Scratchable by back-hoe
  - RMR reduces from 50-60 to <20-30

- At shallow depth, geological structures plays dominant role. But in upper 20-50m, rock stuff is usually severely weathered and geological structures are obfuscated, rather soil like behaviour becomes dominant.
- Role of water is crucial.
- Blast Vibrations affect profusely in weathered rockmass than Un-weathere mass. Instead of passing, shears it
- Mode of failure : Mostly circular or rockmass failure
- As a result- slope design becomes complicated:


Circular failure

Weathered properties: Difficult to model



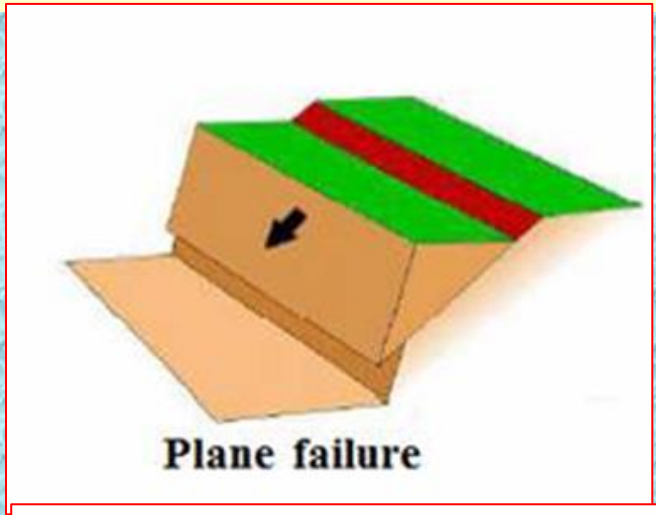
For normal construction materials, e.g., steel and concrete, the mechanical behaviours are Continuous, Homogeneous, Isotropic, and Linearly Elastic (CHILE)

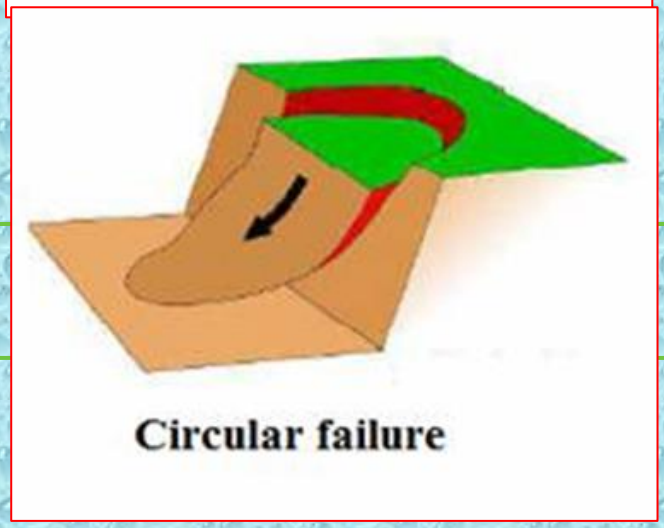
However, rocks are much more complex than this and their physical and mechanical properties vary according to scale. As a solid material, rock is often Discontinuous, Inhomogeneous, Anisotropic, and Non-linearly Elastic (DIANE)

COST OF ACCIDENT: A case study

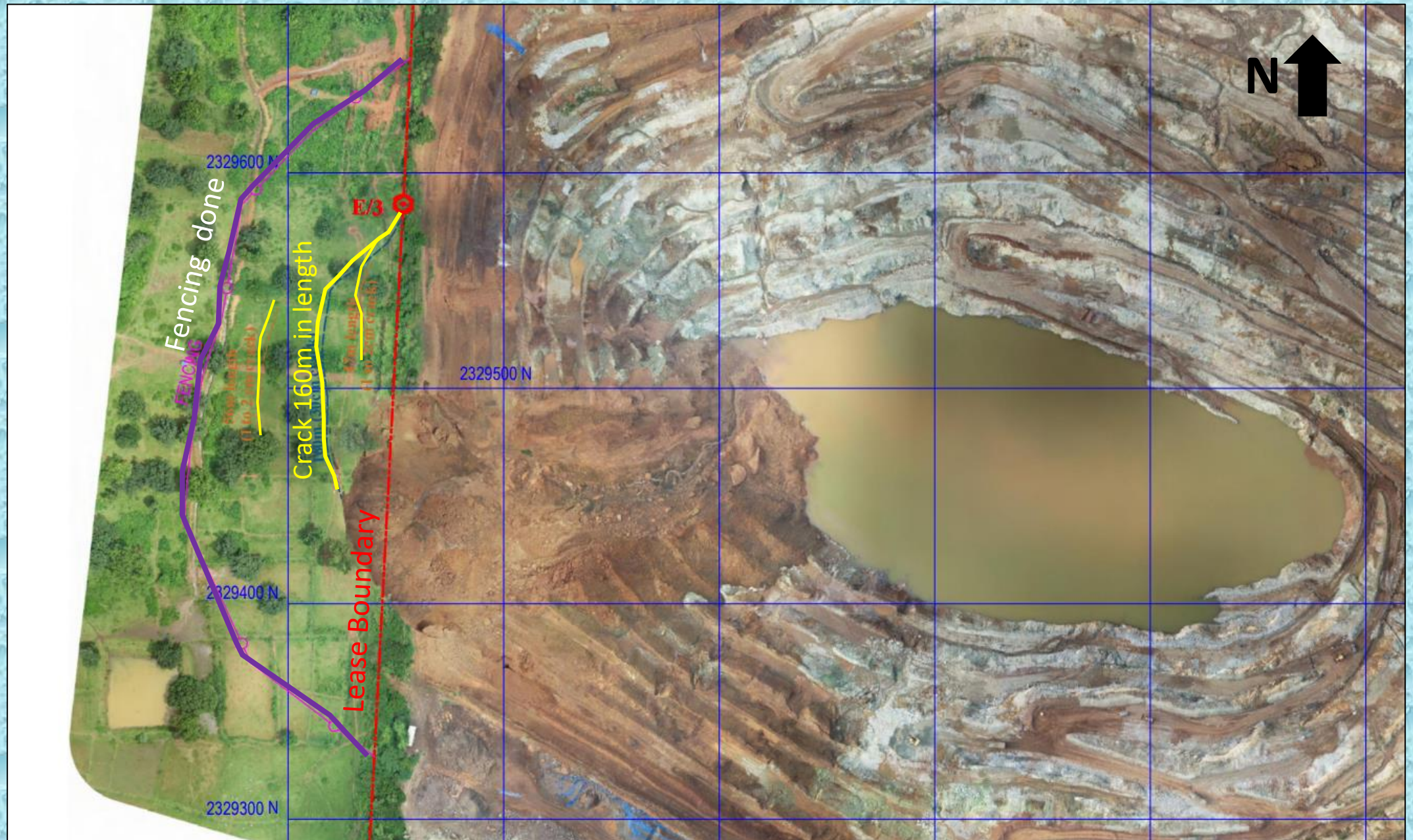
Pit Slope Failure at A Chromite Mine
Dtd. 15th Aug'2022

- Weathered rockmass upto 300m
- Serpentinite, Limonite, Laterite, UCS < 5MPa
- Rock structures like bedding planes: Not visible in Limonite, In Serpentinite, beddings just for name shake
- In-rush of rain water: Plays havoc
- OASA < 33° for a depth of 125-150m
- Poorly read by Radar: Circular failure, Crest moves vertically down- poorly captured, only toe bulges.
- Warning time may be 12 hours to one week.

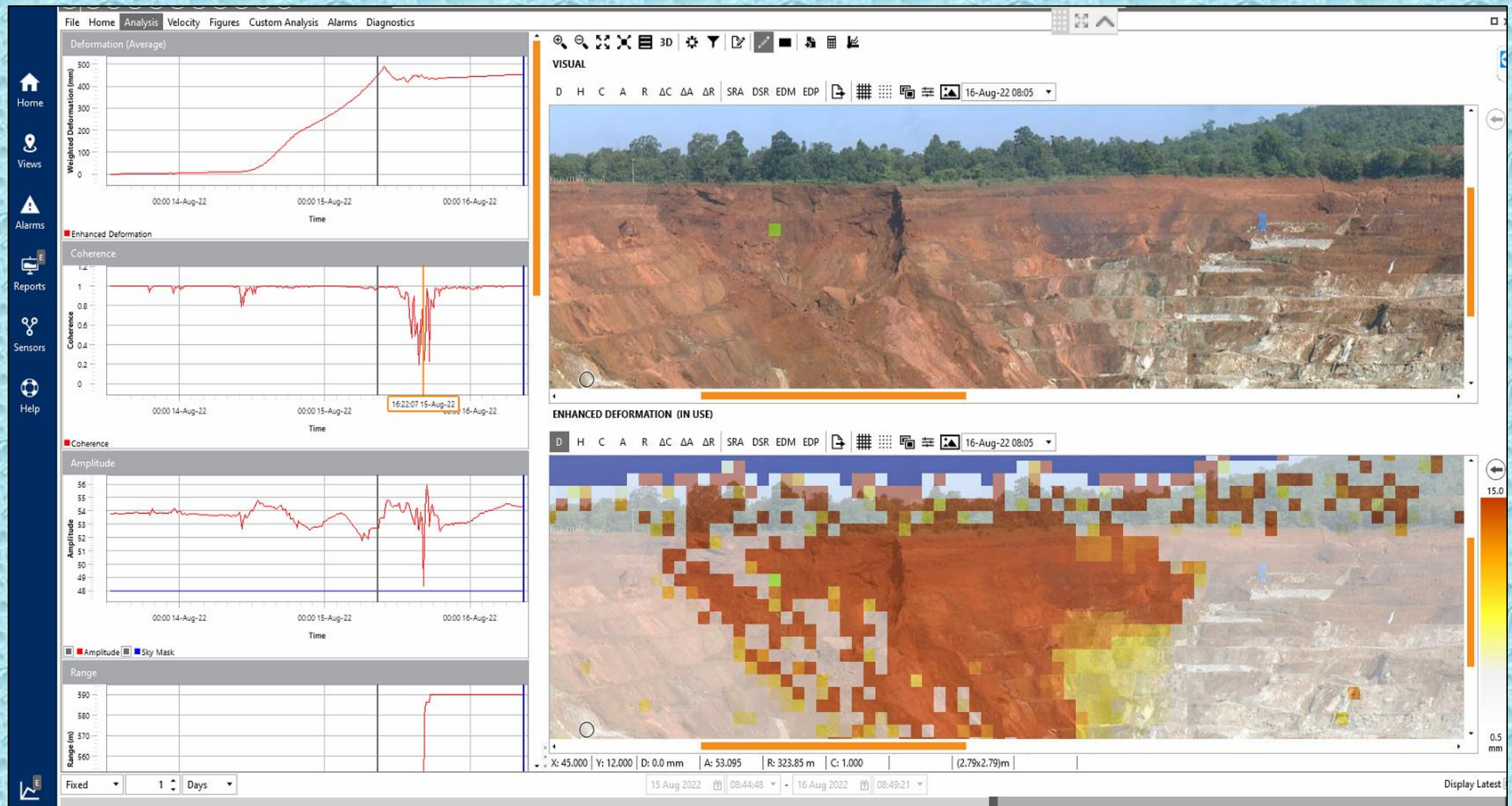




DRONE IMAGE SHOWING THE COLLAPSE AREA

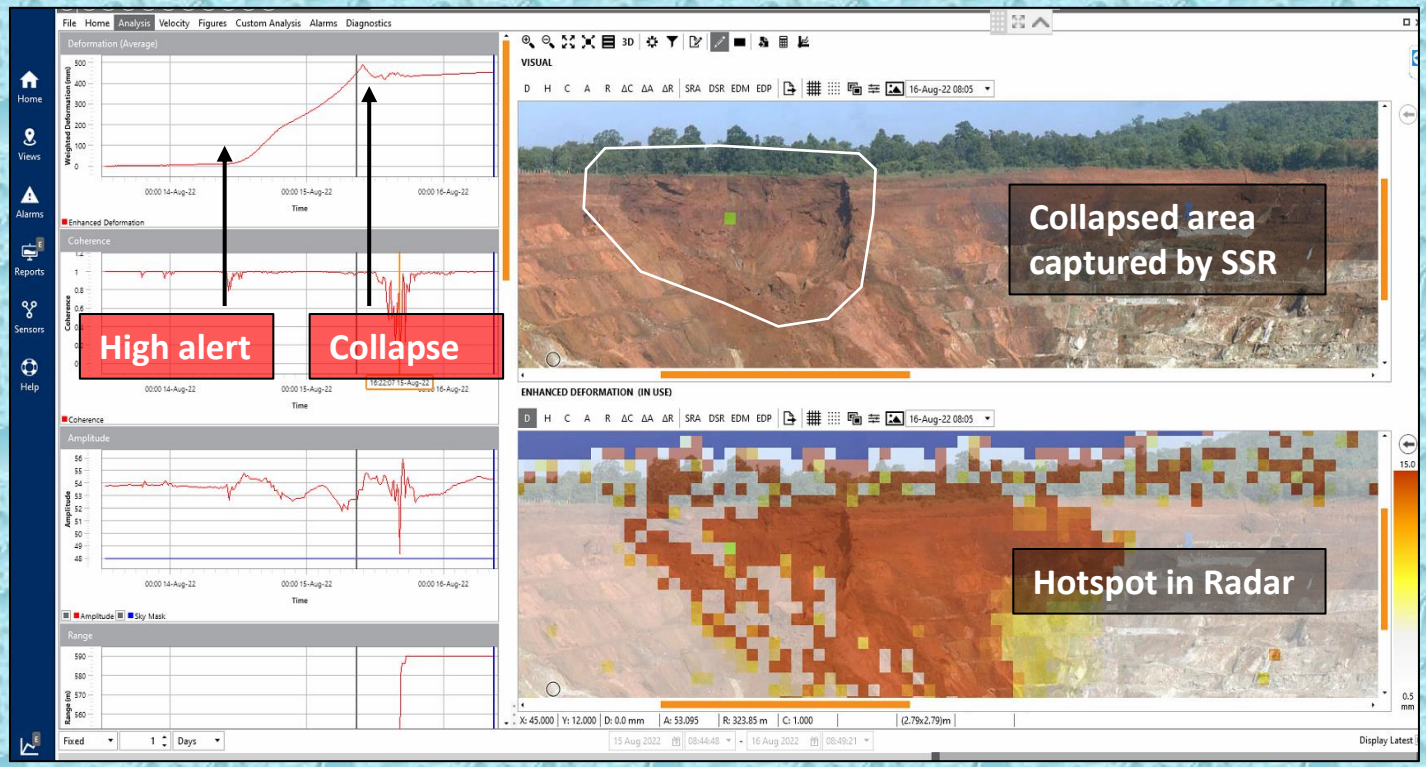


Radar Monitoring



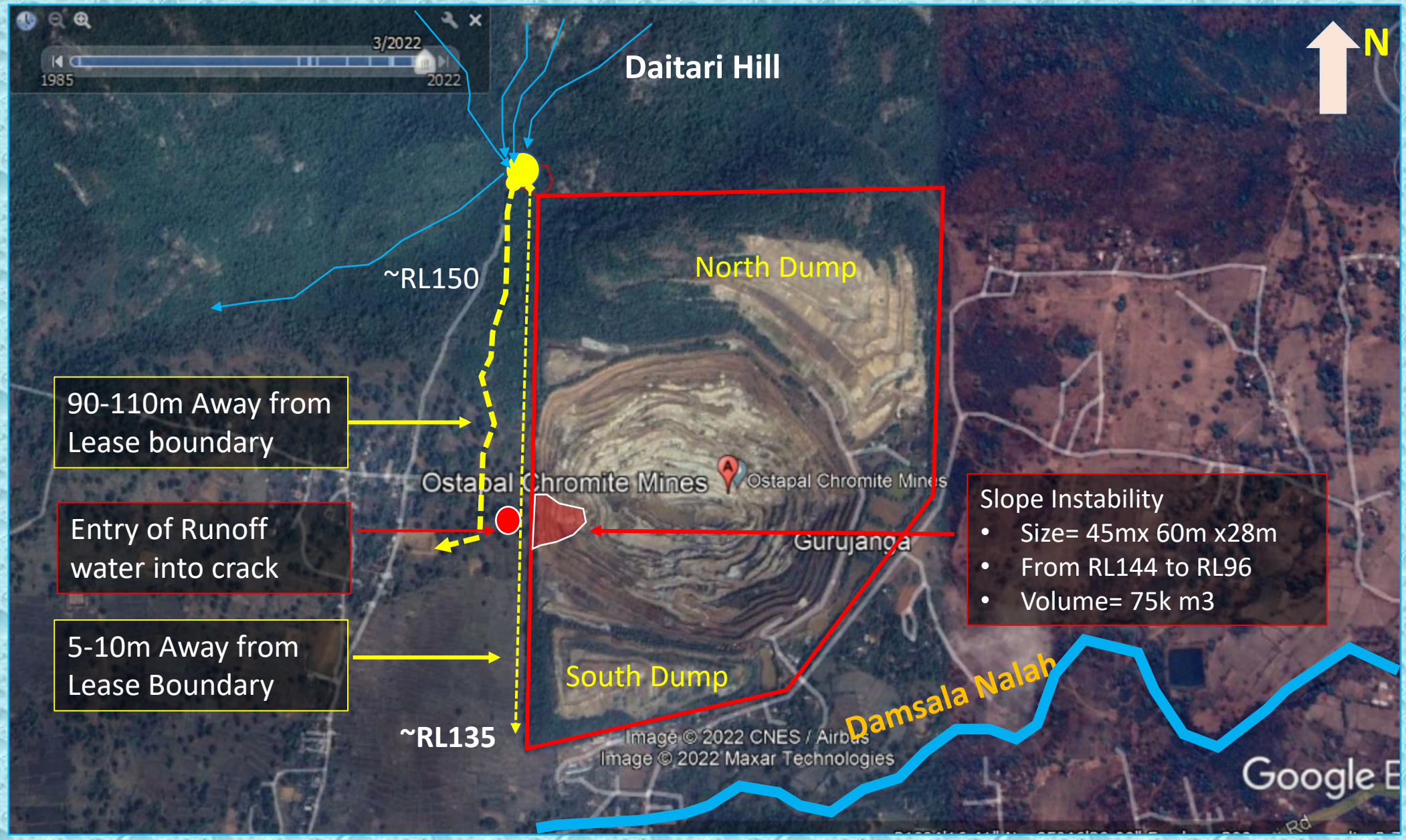
CHRONOLOGY OF THE INCIDENT

1. Movement Observed Through SSR	11th Aug'22; 5:30PM
2. Physical Checking at Site	11th Aug'22; 5:40PM
3. Communication to shift incharge for restriction of man-machinery in the influence zone	11th Aug'22; 6:30PM
4. Crack & water inrush observed on top surface	12th Aug'2; 9:00AM
5. Water diversion from forest area outside mine boundary to prevent entry of rain water	12th Aug'2; 1:00PM
6. Continuous Heavy Rain on 13th and 14th Aug	On 13th & 14th Aug
7. High Alert on slope failure declared for complete restriction of man-machinery	14th Aug'22; 4:30PM
8. Slope Collapse	15th Aug'22; 4:10PM

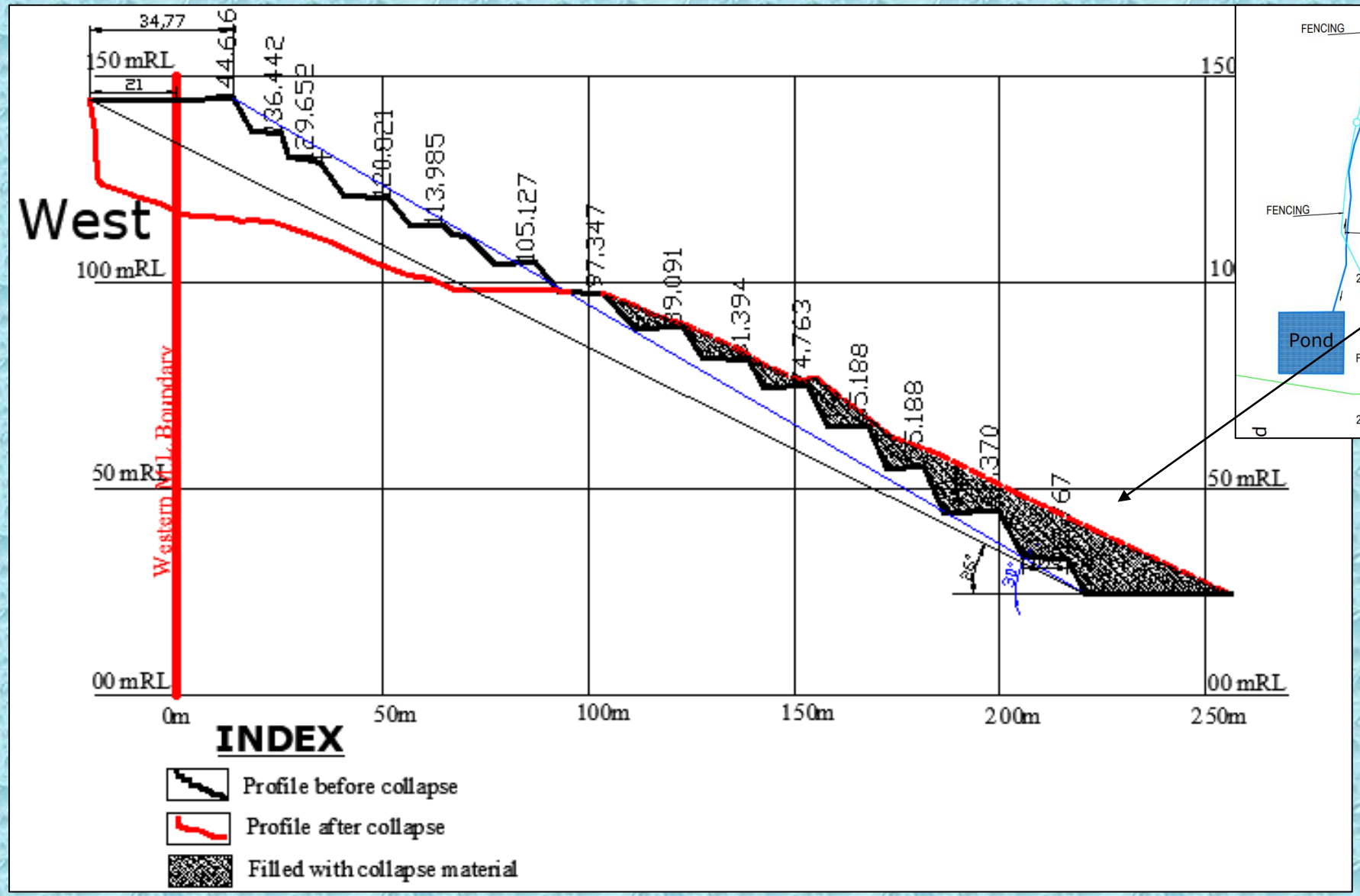


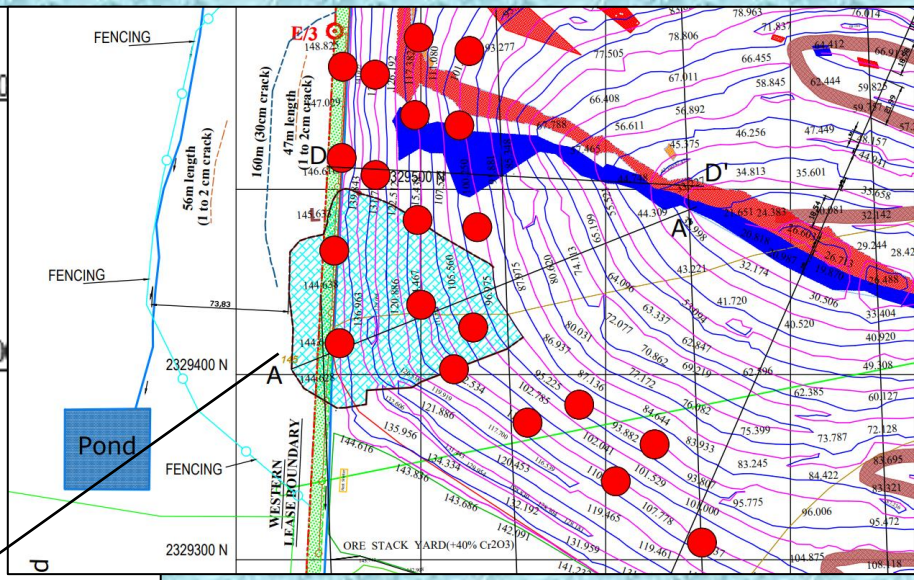
- Cumulative Movement at The time of failure= ~300mm
- Velocity at the time of failure > 10mm/ hr
- Total movement after failure= ~750mm
- Total movement zone= 15k m2
- Collapsed zone= 5k m2
- Size of the collapsed area= 45mx 60m x28m

LOCATION MAP & OTHER DETAILS OUTSIDE MINE BOUNDARY

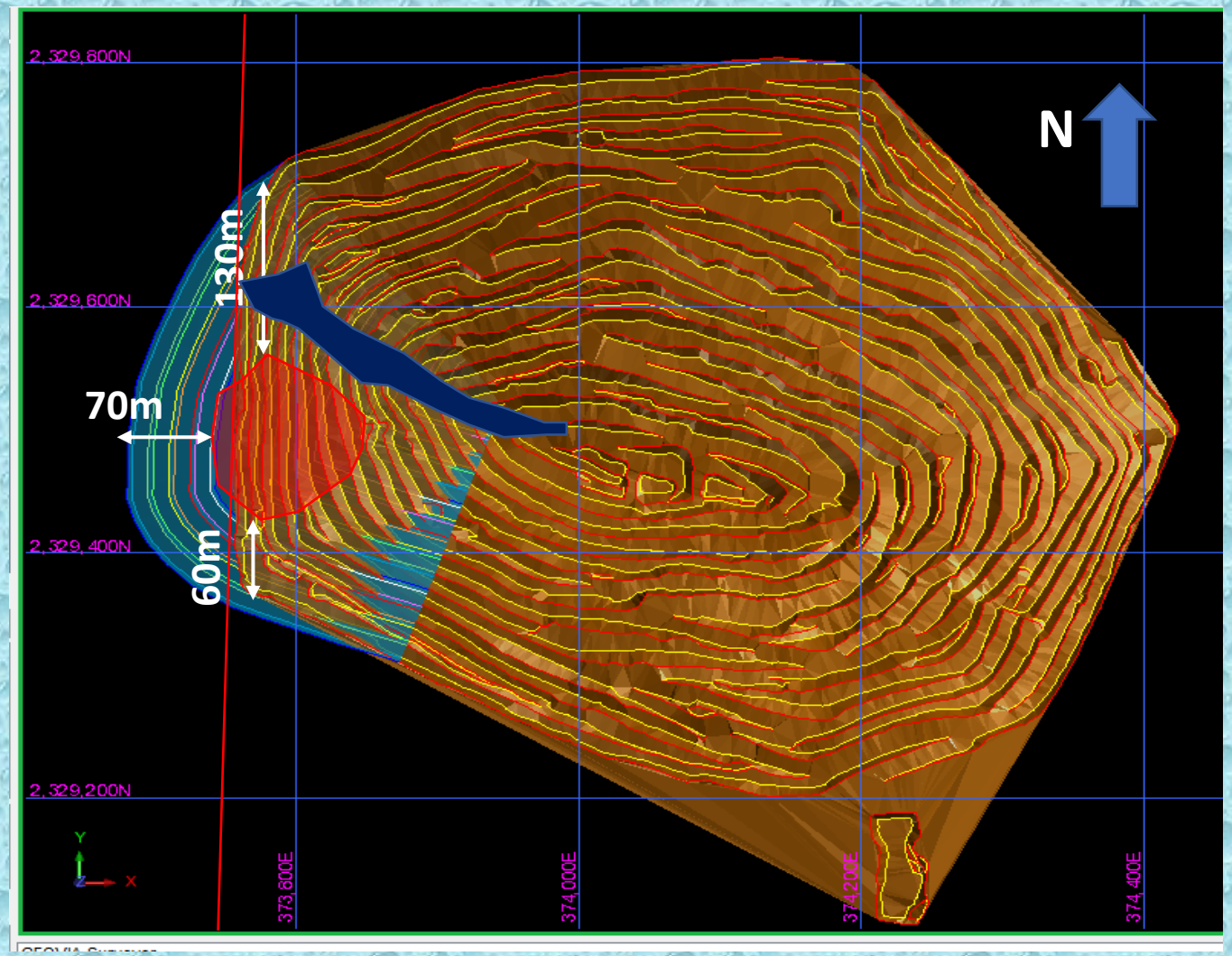


SECTION ALONG A-A' SHOWING – BEFORE AND AFTER PROFILE



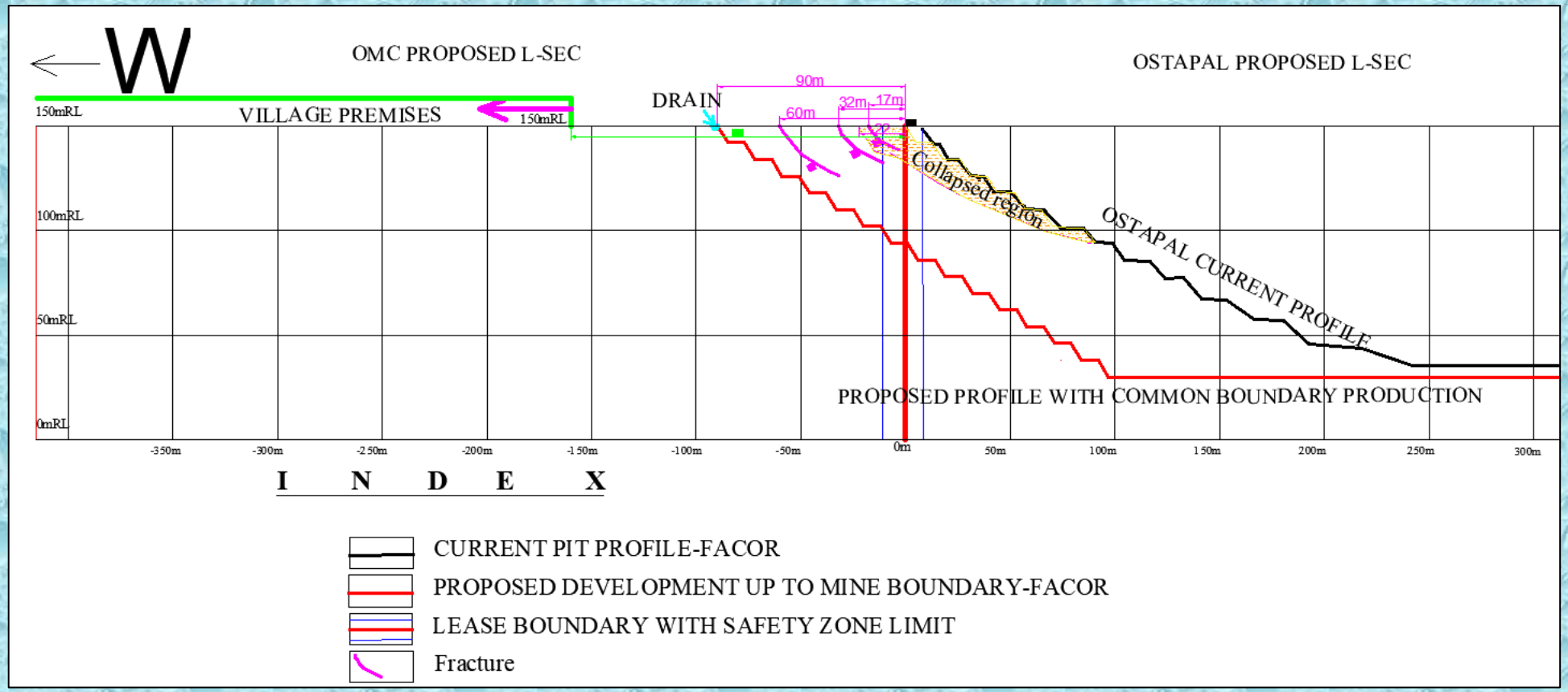


PROPOSED RECTIFICATION WORK



- Development from RL150, inside Kalipani lease
- At the surface, the extension of development shall be 60m away from the failed zone at southern side, 70m away at western side and 130m away from the failed zone at northern side
- Total volume to be handled – 11 lakh CUM Bench profile considered- 8m x 8m and 70 degree bench angle with overall pit slope angle less than 30 degree, which shall be further relooked after completion of the scientific study

PROPOSED RECTIFICATION WORK



- Development from the surface (RL150) to pit bottom, starting in Kaliapani lease, 90m away from the common lease boundary
- Total Volume to be handled = 11.0 Lakhs CUM,
- Extension of the development to be done 60m away from the failed zone towards southern side and 130m away from the failed zone towards northern side

Cost of an Instability: Generalized

An instability may involve:

Loss of life

Damage to equipment

Loss of production and its pace- jeopardizing all the business plan

Cost of one instability:

- **Compensation/ man- Rs. 20-25 Lakhs**
- **Drill Machine Rs 1 Crore**
- **Excavator Rs. 3- 34 crores**
- **Dumper Rs. 1 – 17 crores**
- **One day production @10,000 t= Rs. 25,00,000 = Rs 25 Lakhs**
- **±**
- **Mine Manager: Litigations & Stigma Company : Dent in Image/ Brand Name**

Cost of instability- case study

- 11 lakh cum material to be handled if planning for off-loading or push back
- About 22 lakh tonne
- Costing Rs 100 crores (Rs 450 a tonne)
- Time to be taken 11 months @ 1 lakhs cum per month
- No room available to stack 22 lakhs tonne of waste

Namibian Pit- Shallow Pit collapsed: Rock mass failure

- One wall collapsed at depth of 80m in Nov 2020
- Injured 13, involved 3
- 2 dead body recovered after 6-8 months incurring Rs. 200-250 Cr.

Namibian pit- more than a dozen injured and 2 causality- a dead body removed after 6 months at Rs 250 crores

Shallow marble mine : Totally collapses in rains of Aug 2022 in Makrana- Borawad

The way forward: The Smart Slope Management

Fundamentally, slope management consists of :

A. Proper slope design using scientific studies

B. Monitoring health of the mine slopes

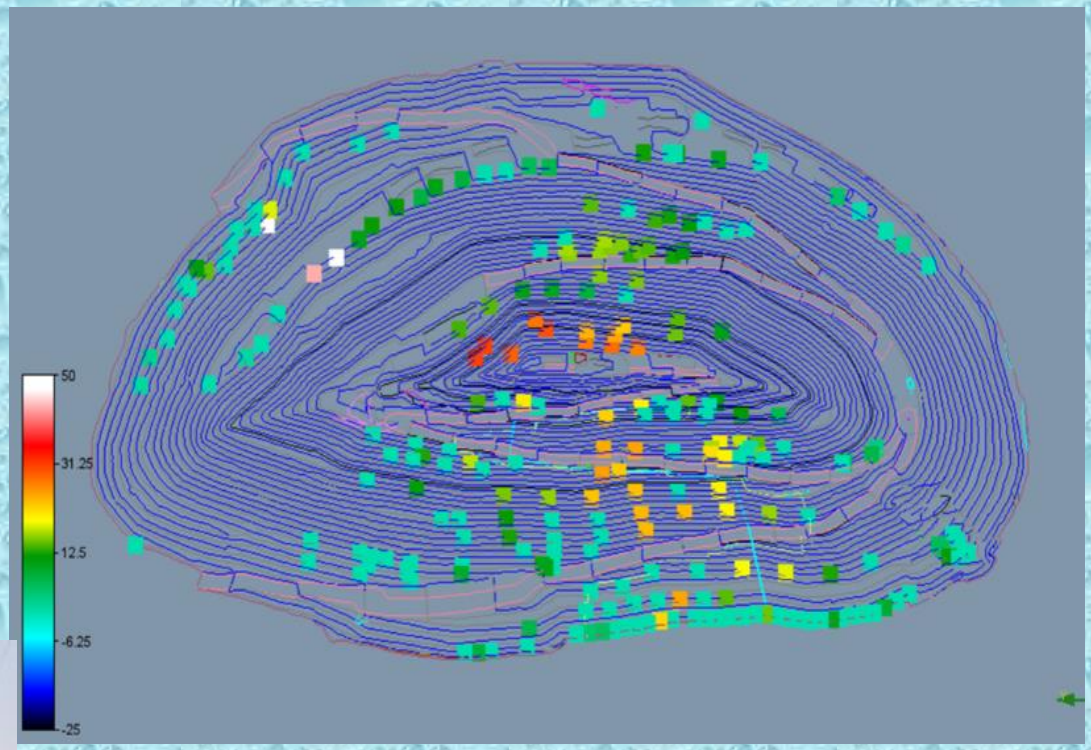
C. Enhancing stability of the slope by minimizing the effects of adversely affecting factors

D. Prediction of failure and formulating Trigger Action Response Plan (TARP).

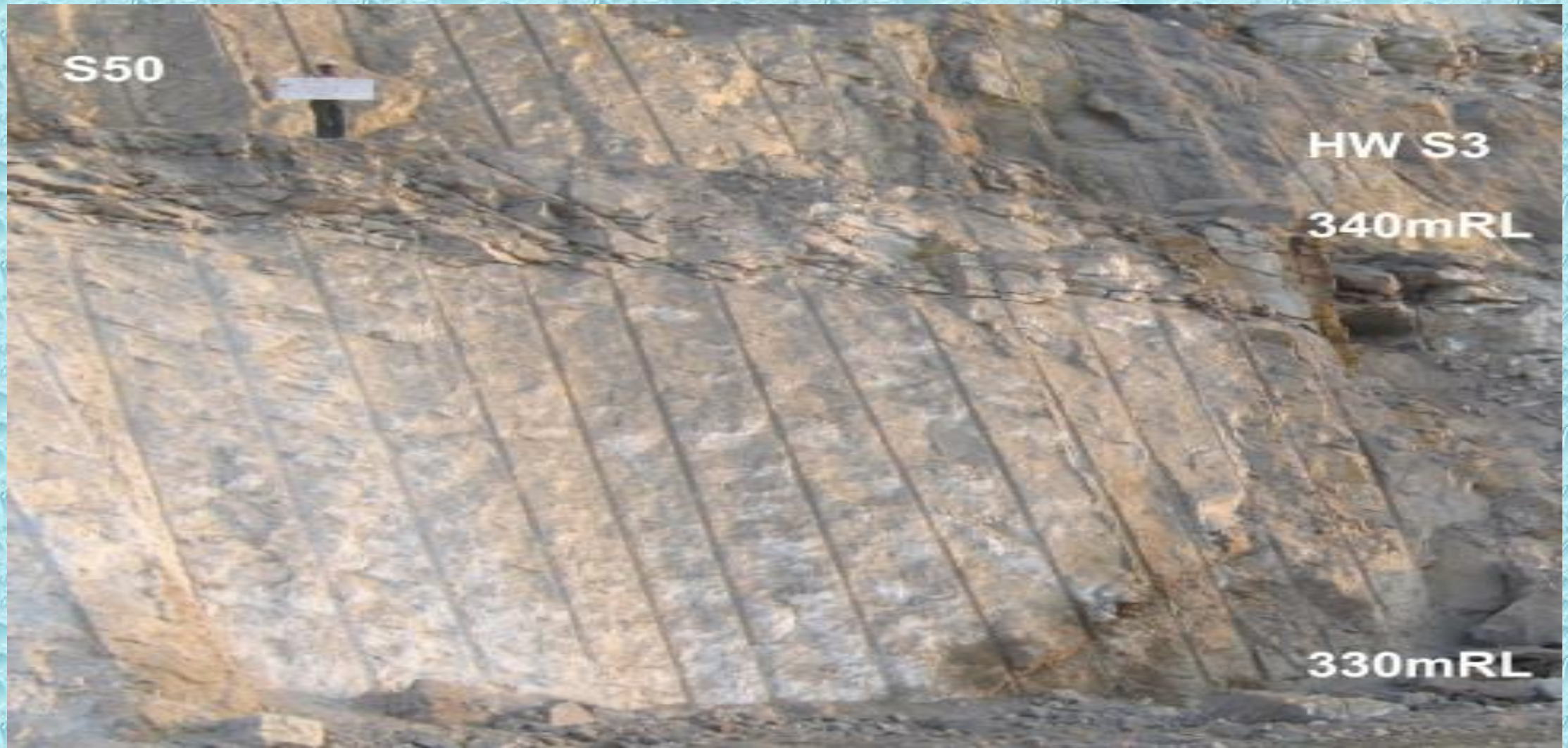
A. Proper design

- Govt run institutes : few , takes longer time, costly
- Teaching Institutes: Few Faculties (Envn), (Raj: 1 +2), (Guj 3-4),
- **Needs permission to Private Institutes/ Consultants on International Model: Criterion based: Specify Experience, Educational Qualification, etc.**
- **Private sectors: Valuable contributing in Health, Education, Defence sectors, Space, _____**
- International Examples:
  - Australia: Catering world wide technical support: AMC, Golders, SRK, **Beck- single man army contributing globally.**
  - England: Golders, SRK,
  - USA: Itasca, Golders, AMEC,
  - India: ???

B. Slope Monitoring: Strategic & Critical area



C1. Enhancing stability : Minimize the blast induced damage



C2. Deal with geological discontinuities

C2A. Pre-stressed cable bolting or shotcreting

Pre Stress Cable bolting:
Equipment used in Stitching Activity

Drill Rig

Lifter

Grouting Machine

Wedge plate, Feeding tube & Breathing tube

Wire rope

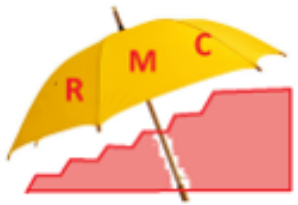
Wedge Barrel

C3. Depressurization of slope walls

Conclusions

- Shallow mines are rather more prone to instability
- Normally in weathered rocks:
  - difficult to simulate
  - there are poor signals/ markers of instabilities and difficult to predict failure well in advance.
- Instability can cripple a mine without capturing precursors
- Cost of accident is very high
- **Smart Slope Management: Game changer**
  - Properly design the mine slopes
  - Carry out slope monitoring

Beginning of :
Smartly managing the mine slopes with zero tolerance for accidents



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Thanks MSAK- Unique

Mr. Madhusudan Sb: Also Unique