Determination of Stoping Methodology for Mining Secondary Stopes by FLAC3D

Presented by

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Introduction

- **Mining**

  Extraction of valuable minerals or other geological materials from the Earth, usually from an ore body, lode, vein, seam, reef or placer deposit.

Mining Techniques

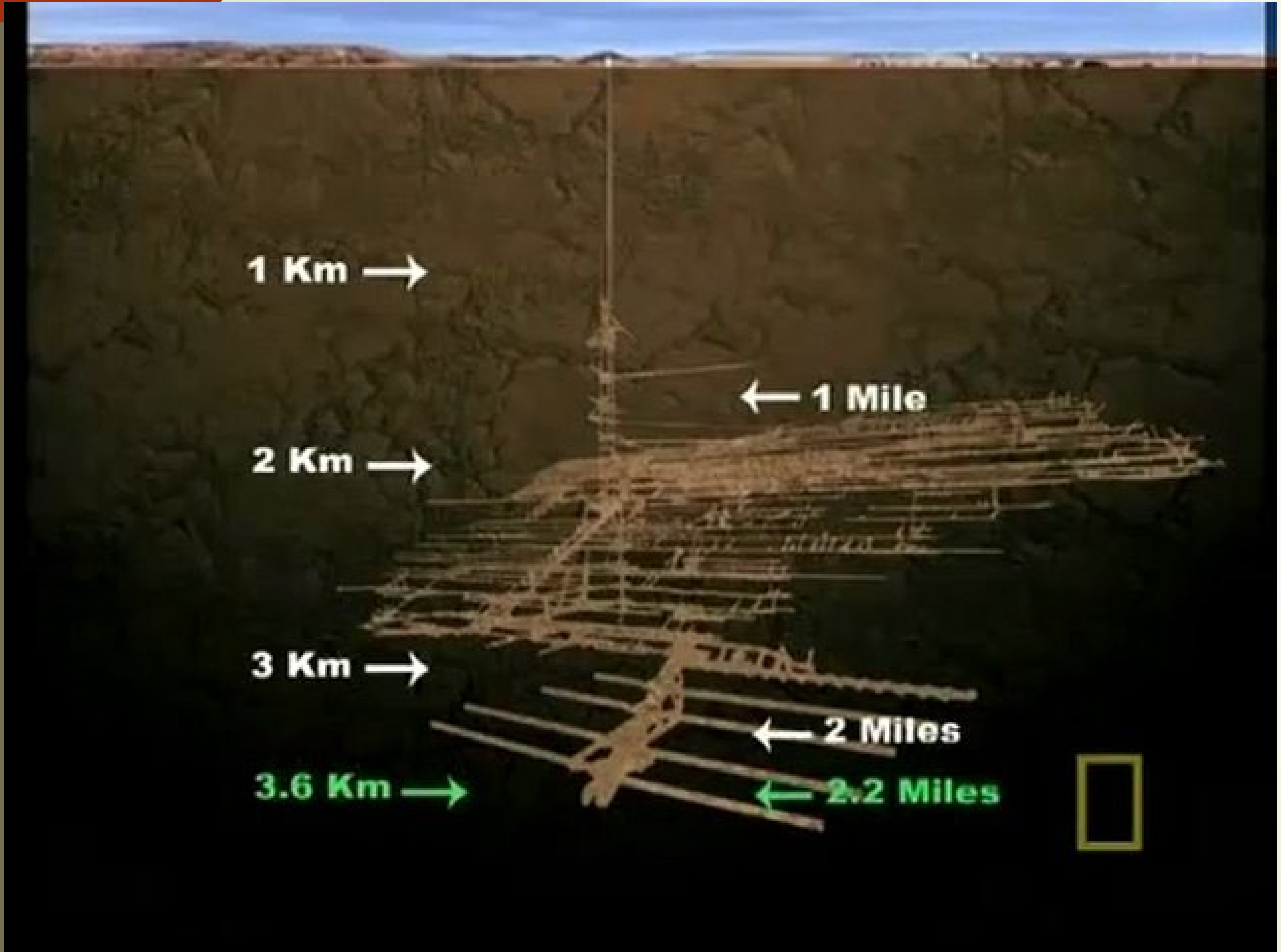
Surface Mining

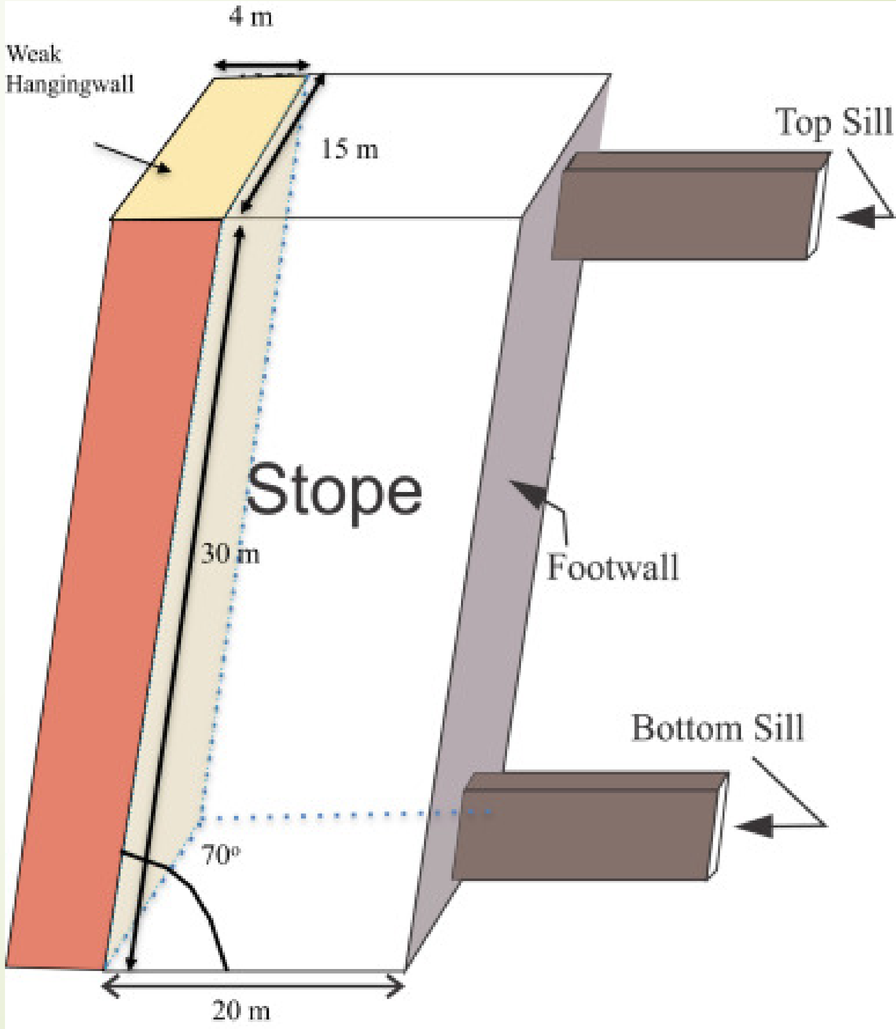
Underground Mining

Bingham Canyon Mine, Utah

Sindesar Khurd Mine, India

Stoping


1 Km
1 Mile
2 Km
3 Km
2 Miles
3.6 Km
2.2 Miles


4 m
Weak Hangingwall
15 m
Top Sill
Stope
30 m
Footwall
Bottom Sill
70°
20 m

Stoping Configuration

Stopes are categorized into
- Primary
- Secondary
- Tertiary

Primary	Secondary	Tertiary
Mined once the backfilling of the adjacent primary stopes is complete	Acting as pillars during excavation of primary stopes	Hosts block access drifts

Mined once the backfilling of the adjacent primary stopes is complete

Locks up a substantial quantity of Ore in a lens

Due to very limited sequential options in deep underground mines, optimization of stope dimensions and stoping configuration forms a most crucial part of mine planning.

FAILURE OF STOPES

Failures are the Steppingstone to Success

Right ?

not TRUE for Rock Mass !!!

- Leads to Loss of Life

& Property

THERE'S NO WAY OUT !

FAILURE OF STOPES

How to Prevent

Mining History

Visual Observations

Periodic Checks

Structural Response or Behavioral Check

Minor Falls

Swelling or Squeezing

Slabbing or Spalling

What's important is . . .

Are these checks,

Continuous !

Real Time !

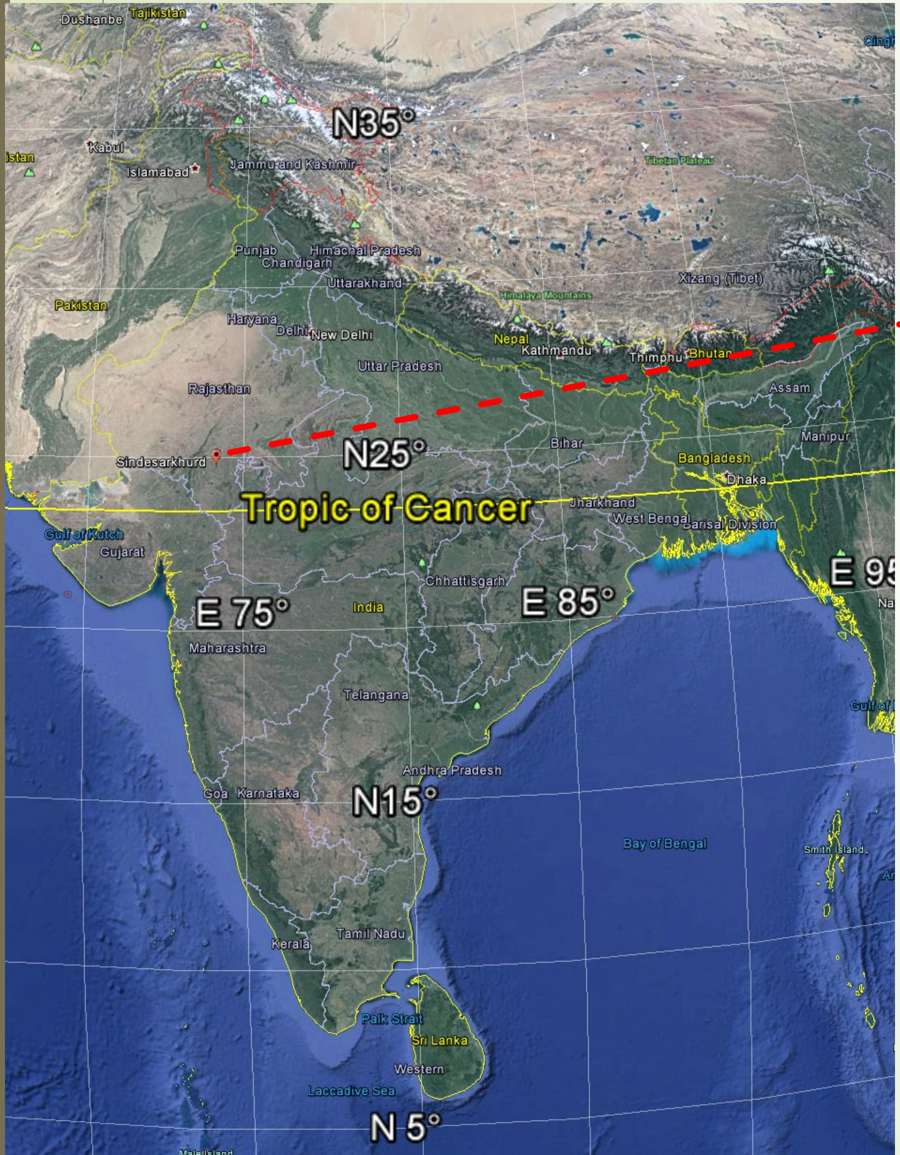
Alarm and Alert !

Ultimate Solution ???

Mine Plan & Design

Case Study

Sindesar Khurd Mine, Hindustan Zinc Limited



Source : Google Earth

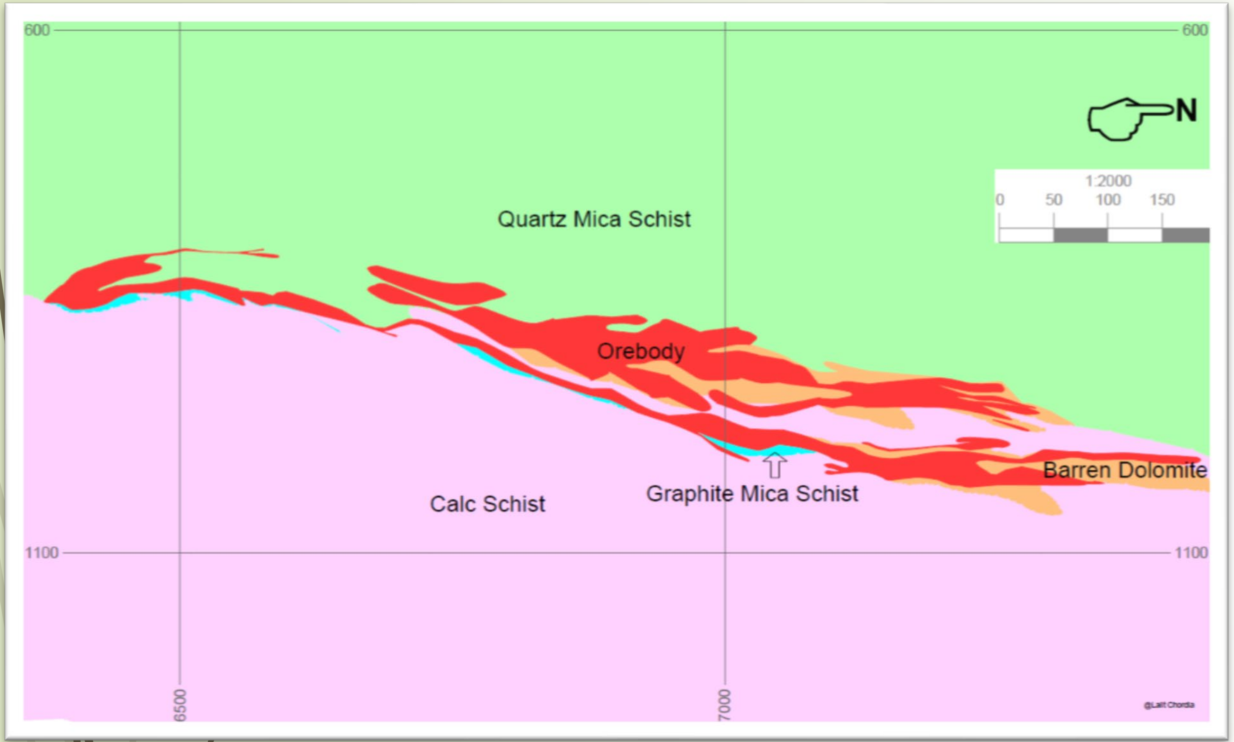
India's largest underground mine with production of 4.5 million MT in FY 2018. With average reserve grade of 7%, the mine differentiates itself with its silver-rich zinc-lead deposit, highly mechanised and low cost of operations.

Geology at Sindesar Khurd Mine

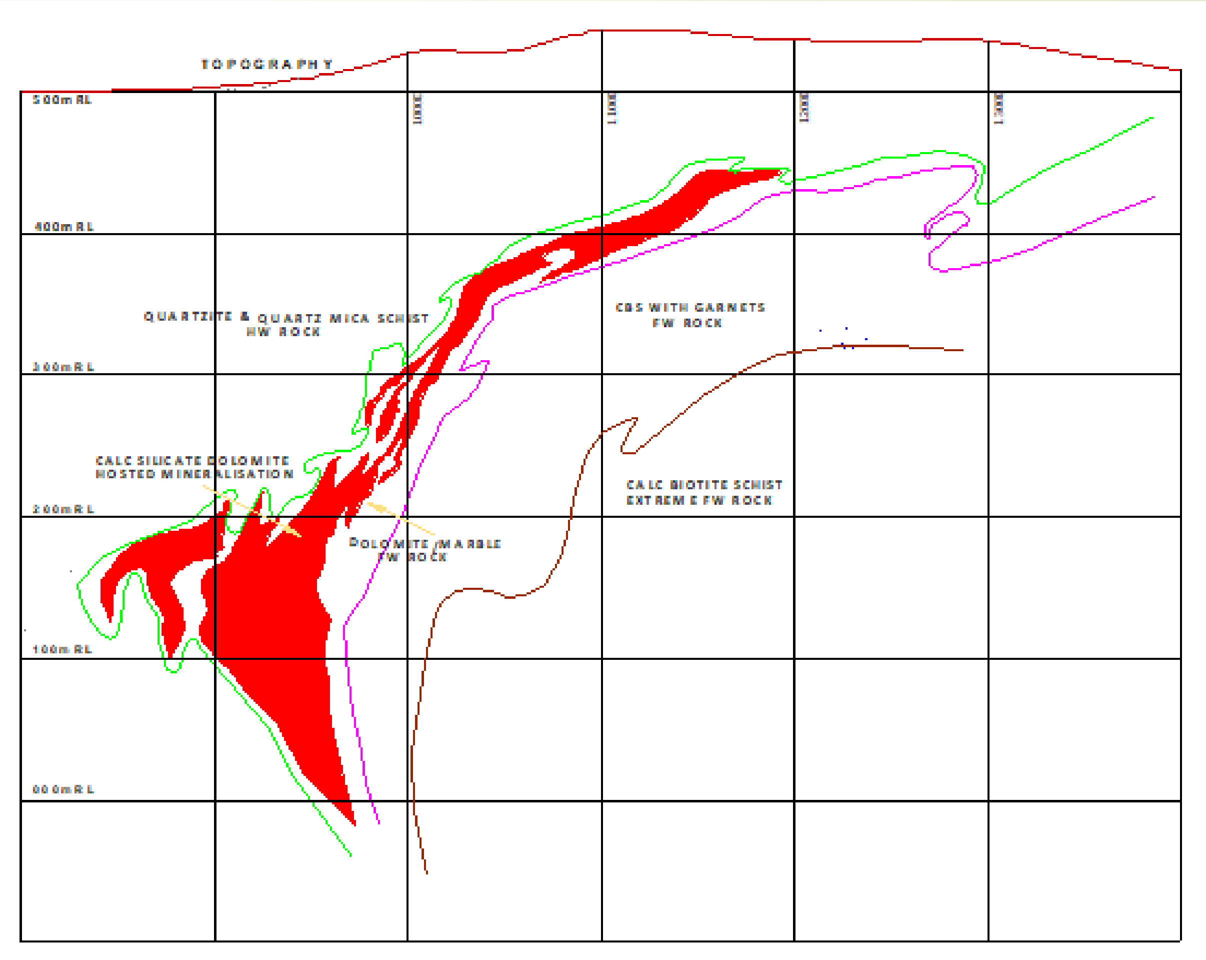
Sindesar Khurd deposit is located in the central part of the eastern limb of the major Dariba-Bethumni synformal fold. The best exposed rock unit in the area is inter-banded mica - schist / chert / quartzite and forms a prominent NNE-SSW trending ridge. The economic concentrations of lead-zinc-silver mineralisation are hosted by calc-silicate bearing dolomite and graphite mica schist. The prominent rock types found in the area as follows:

- Quartz Mica Schist with bands of chert/quartzite
- Graphite Mica Schist with Fe-Pb-Zn sulphides
- Calcareous Garnet Biotite Schist with dolomite
- Calc Silicate Bearing Dolomite with Fe-Pb-Zn sulphides
- Calcareous Quartz Biotite Schist
- Basement Rock (Felspathised schist/gneisses)

Geology at Sindesar Khurd Mine



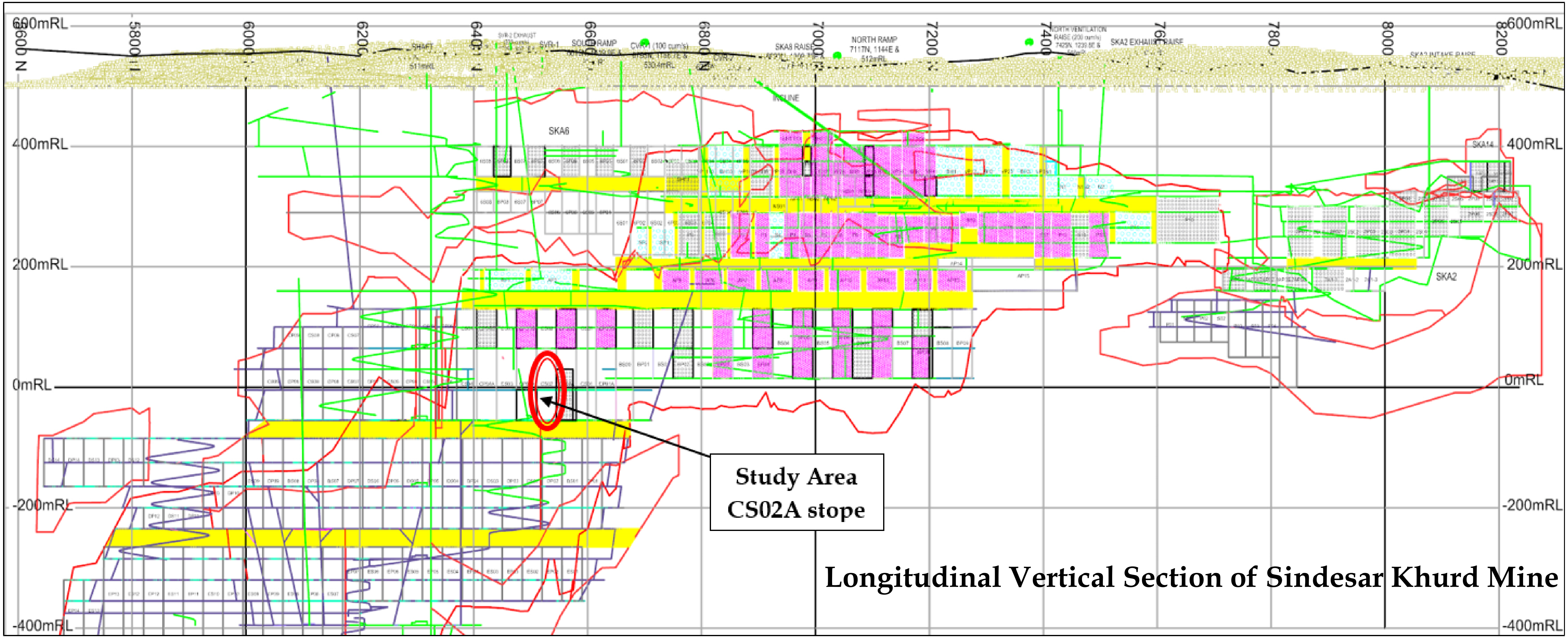
Typical orebody plan of Sindesar Khurd Mine



Typical transverse section of orebody

Mining Method

Blast Hole Open Stoping in Upper block and Long Hole Stoping with Backfilling in Lower block with Primary and Secondary stoping sequence



Longitudinal Vertical Section of Sindesar Khurd Mine

Geotechnial Setup at Sindesar Khurd Mine

Feature	Details
Structure	Eastern limb of regional fold
Strike and its Length	N15°E – S15°W, Length – 2.3 km
Dip	Moderate to Steep (55°-75°) Westerly / Easterly
Host Rock	Calc-Silicate Dolomite & Graphite Mica Schist
Hangwall Rock	Quartzite / Quartz –Mica Schist
Footwall Rock	Dolomite / Calc Biotite Schist
Main Ore Minerals	Sphalerite & Galena
Width of Lenses	2 to 55m
Explored Depth	1100 m from surface
RMR	60-80; very competent HW / FW & totally dry mine
Challenge	Folding, swelling, pinching & branching nature of ore body

$$S_v = 0.0278\,z$$

$$S_H = (13.94 \pm 2.17) + \{(0.0294 \pm 0.0039) \cdot (z, m - 237.0)\}$$

$$S_h = (7.54 \pm 0.58) + \{(0.0137 \pm 0.0010) \cdot (z, m - 237.0)\}$$

Where

S_v is Vertical Stress (MPa)

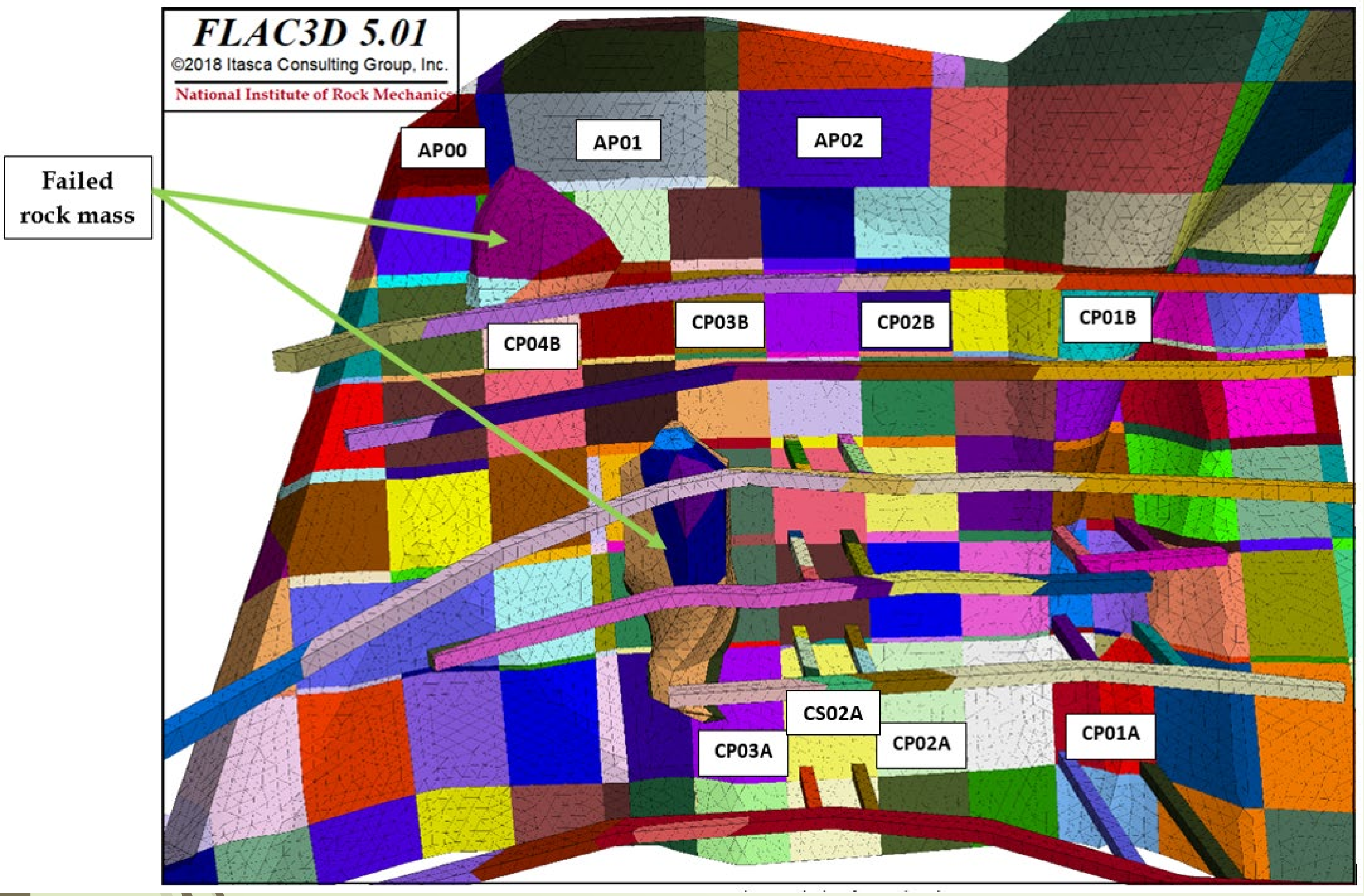
S_H is Maximum Horizontal Stress (MPa)

S_h is Minimum Horizontal Stress (MPa)

z is the depth from surface (m)

The major principal stress (Maximum Horizontal Stress) acts along N20°E$\pm$10° at the mine site. The North direction lies along the Y-axis of the model.

Stoping Methodology for CS02A

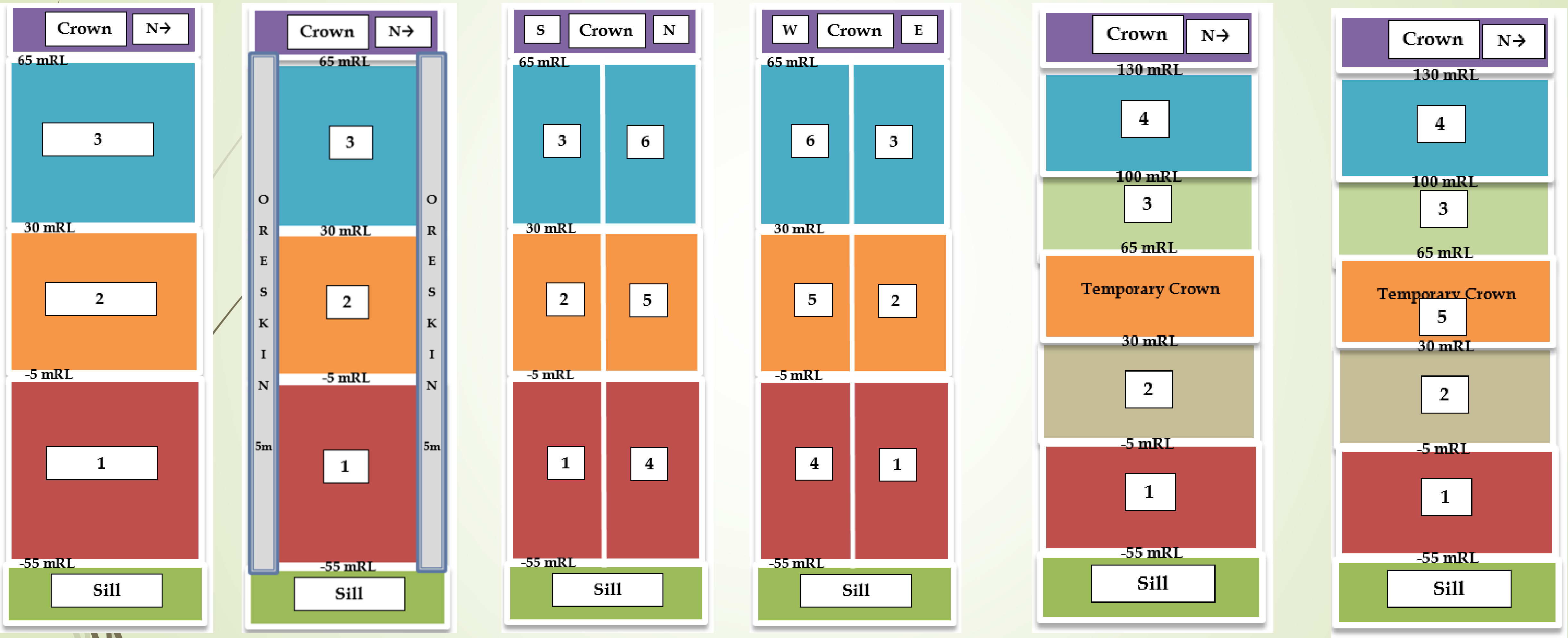


In this study, behavior of the rock mass is studied for safe extraction of ore from CS02A stope for six alternate methods using 3D numerical model developed in FLAC3D software so as to determine the most suitable stoping method.

Model is developed by incorporating true ore body extents along with different lithological layers of Graphite-Mica-Schist, Calc-biotite schist, Biotite Schist and Quartz Mica Schist.

Stoping Methodology for CS02A

Six different stoping methodologies were studied using three-dimensional numerical modelling approach.



Case 1 – Stoping sub level wise

Case 2 – Stoping sub-level wise leaving ore skin

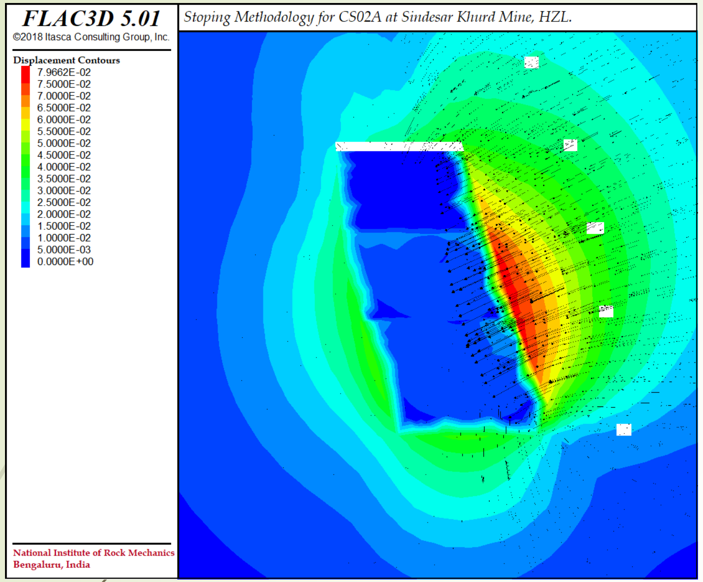
Case 3 –Split stoping method (north south)

Case 4 – Split stoping method (east – west)

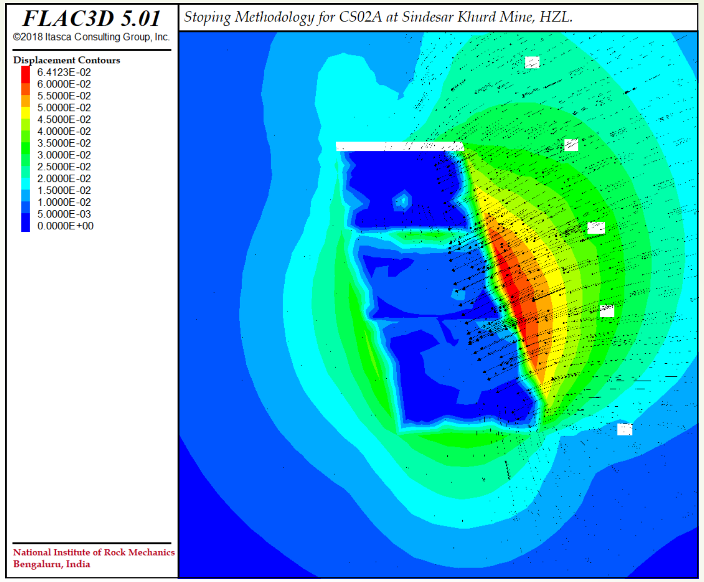
Case 5 – Stoping sub-level wise with temporary crown unmined

Case 6 – Stoping sub-level wise (part a – part b – temporary crown)

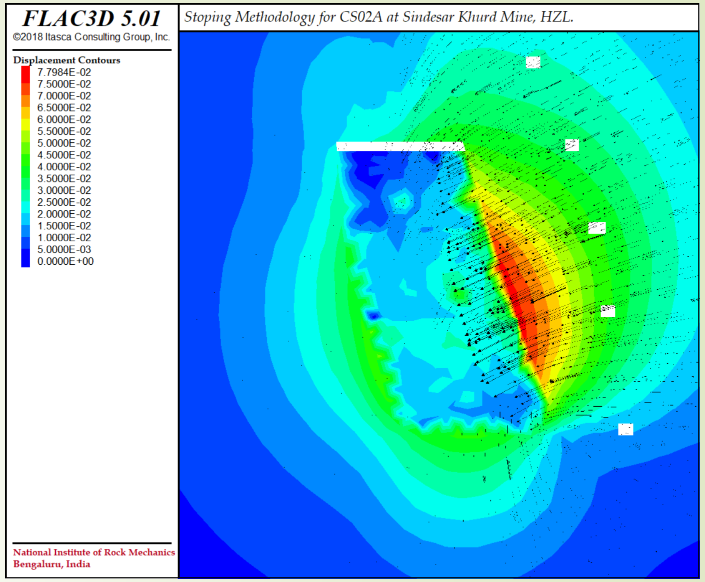
Results - Displacements



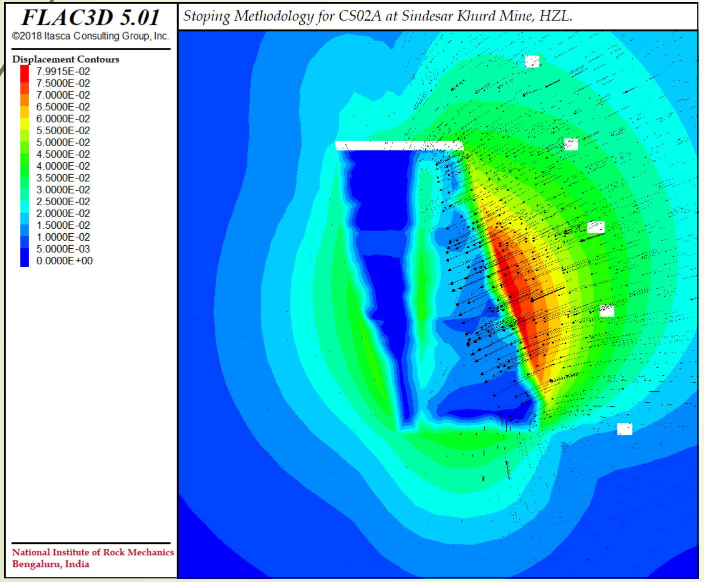
Case - I



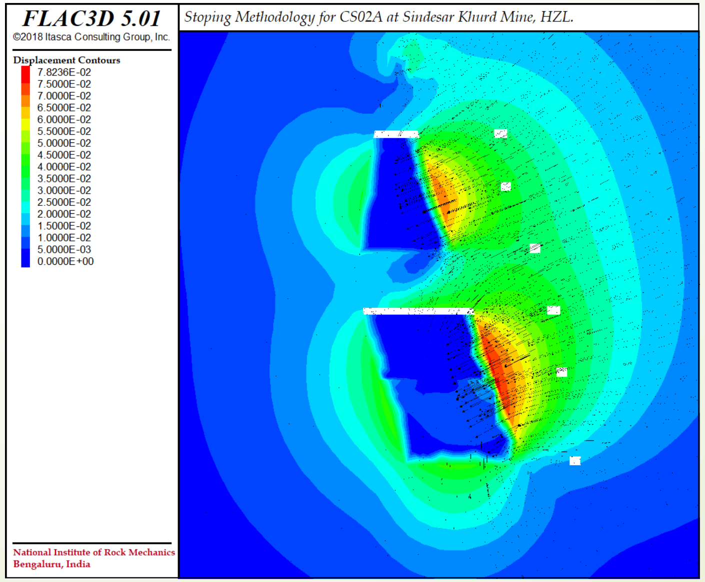
Case - II



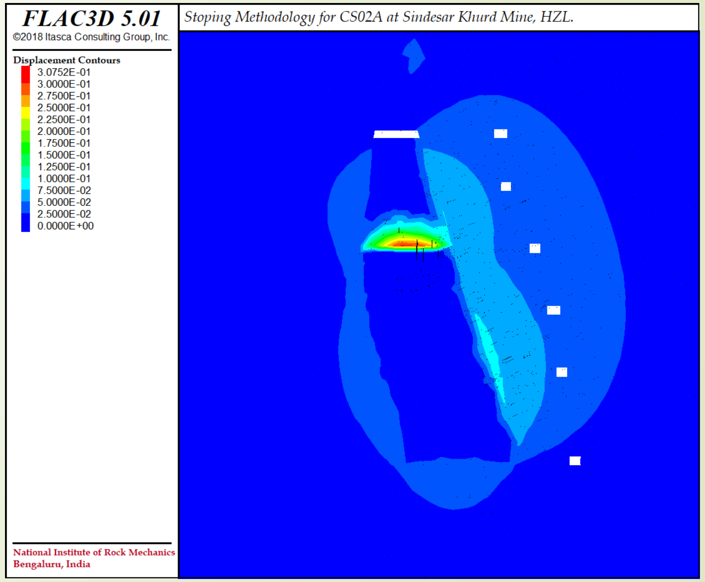
Case - III



Case - IV

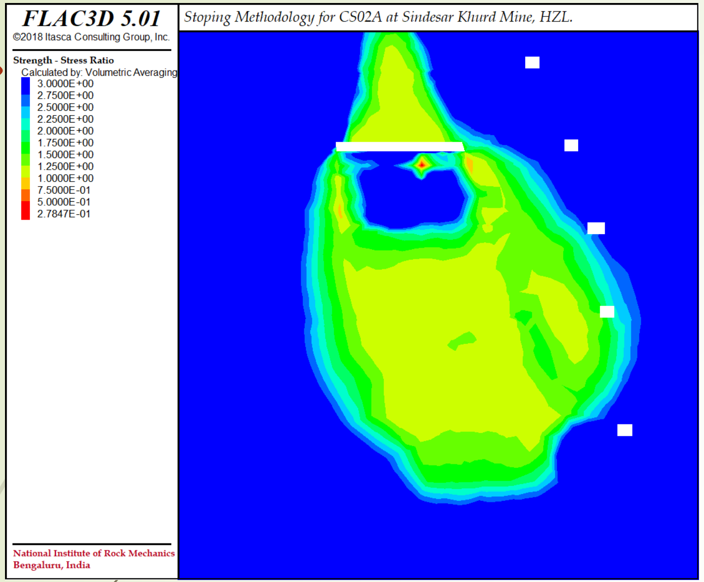


Case - V

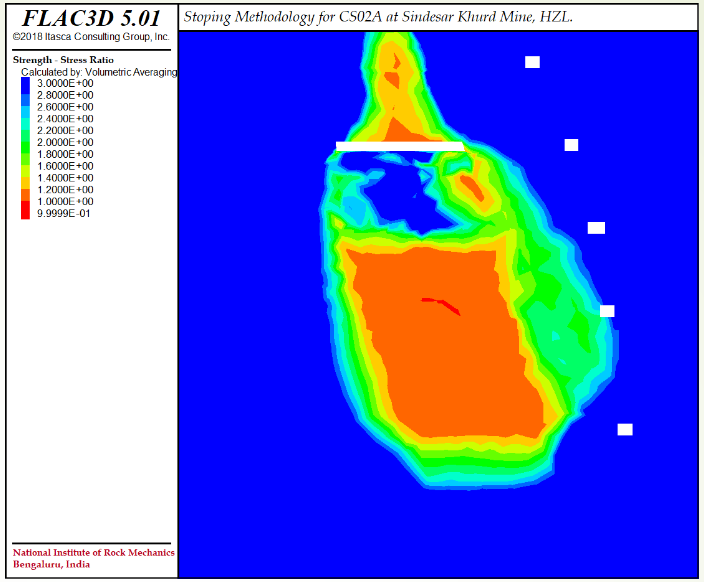


Case - VI

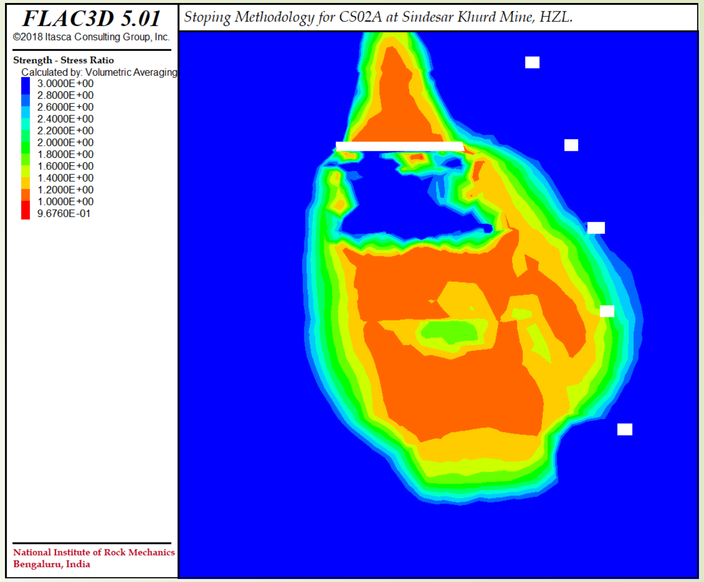
Results – Factor of Safety



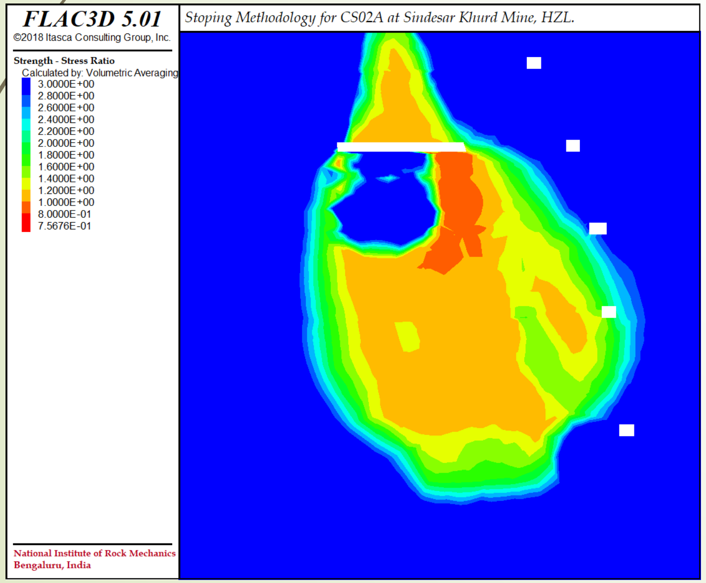
Case - I



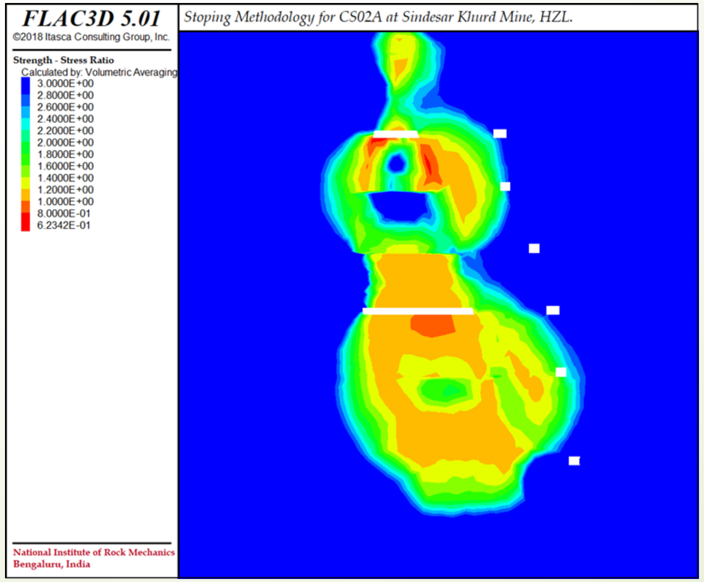
Case - II



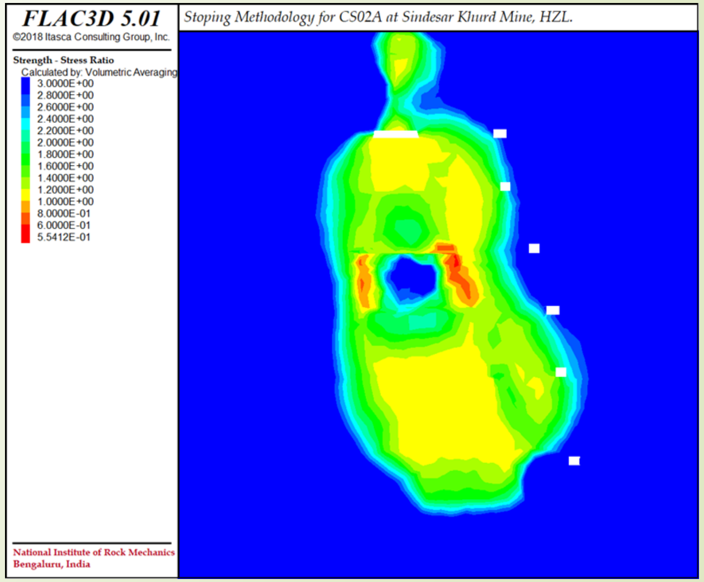
Case - III



Case - IV

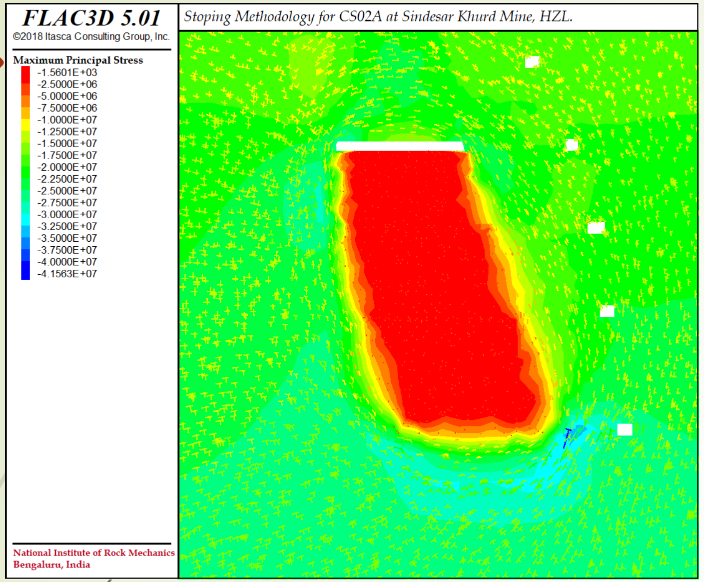


Case - V

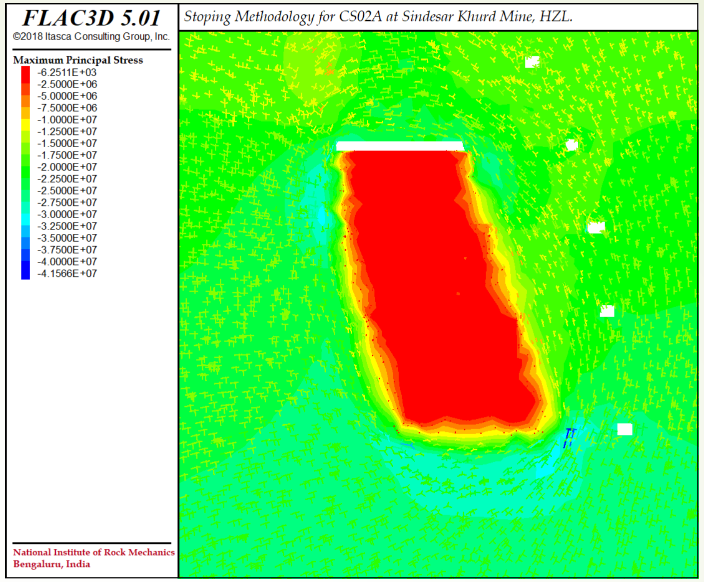


Case - VI

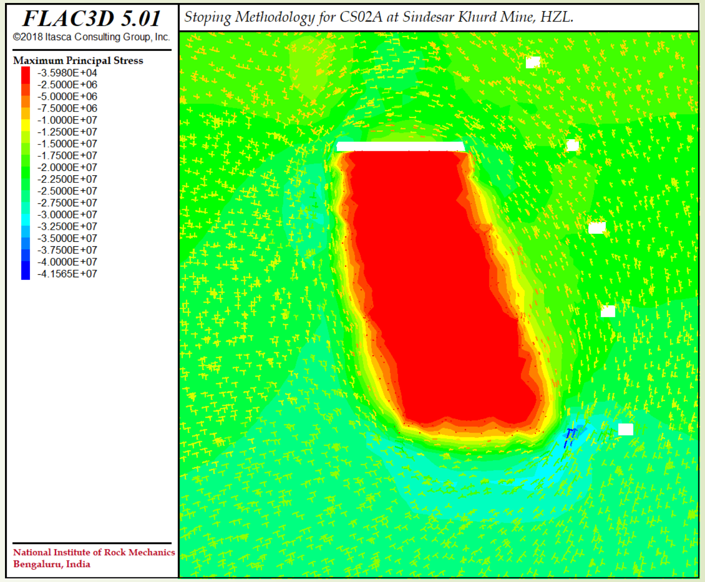
Results – Maximum Principal Stress



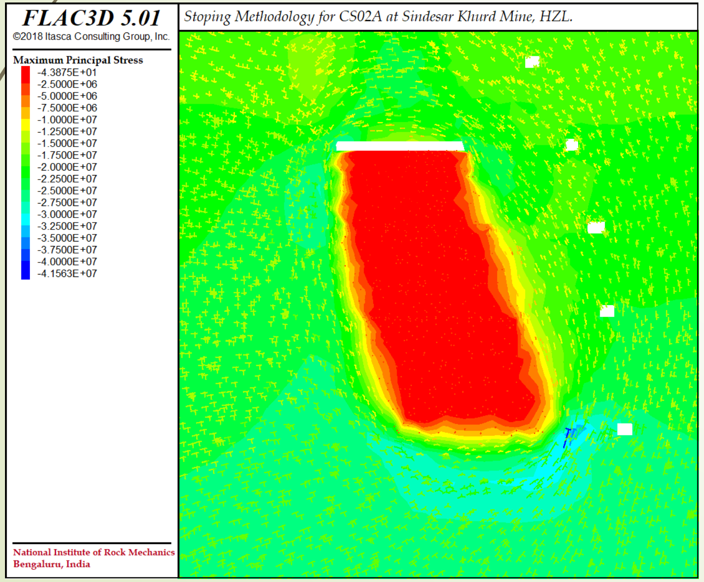
Case - I



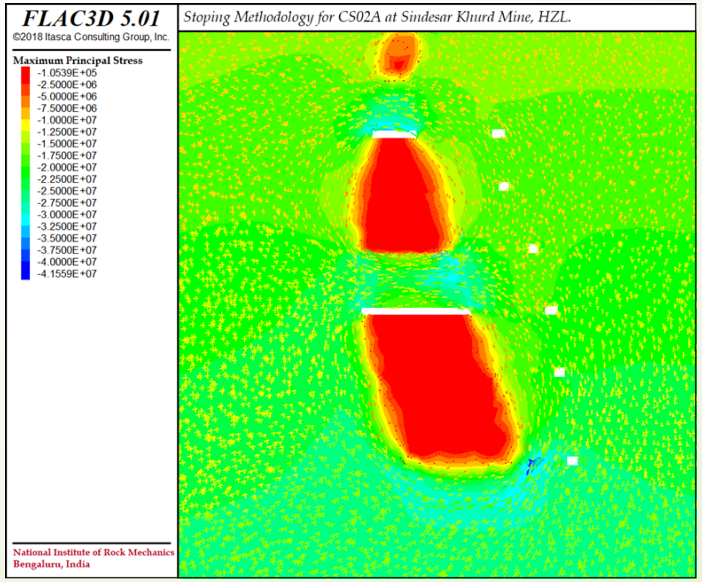
Case - II



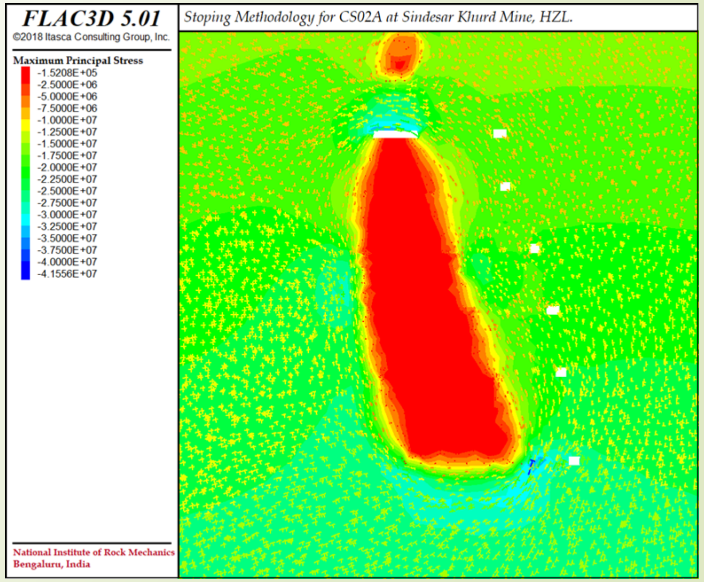
Case - III



Case - IV

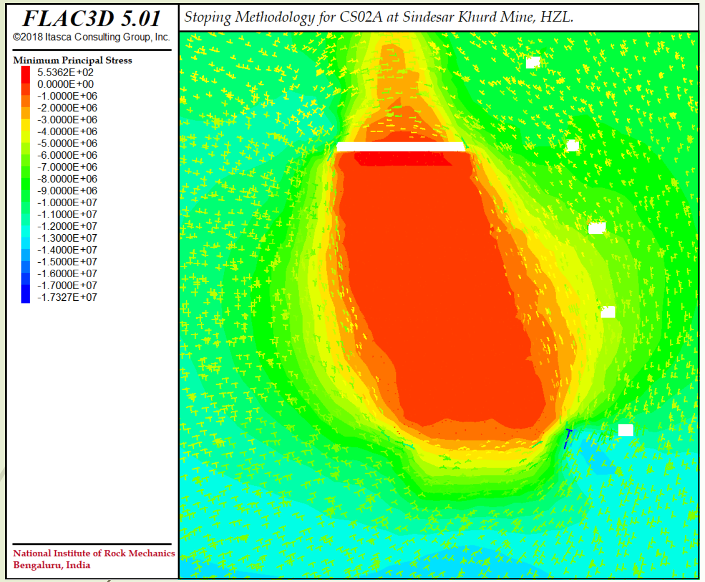


Case - V

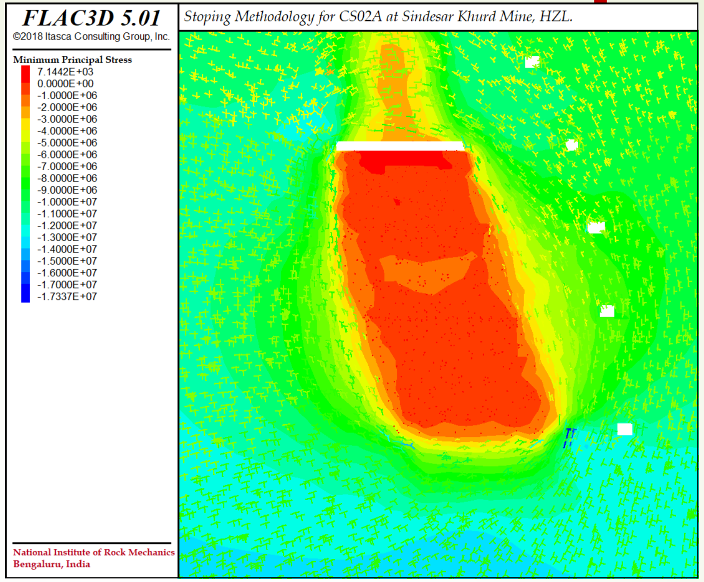


Case - VI

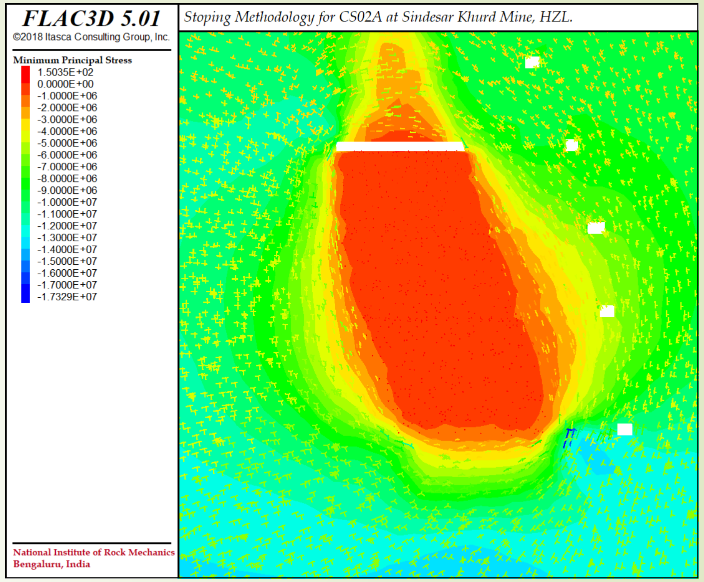
Results – Minimum Principal Stress



Case - I



Case - II



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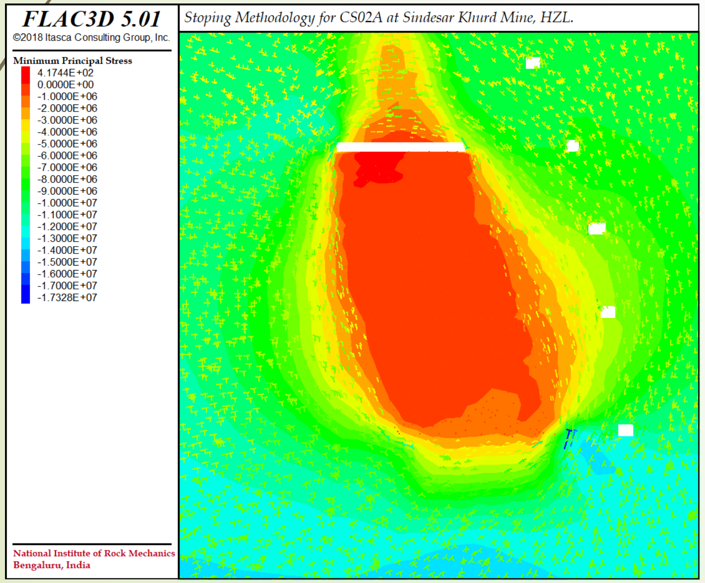
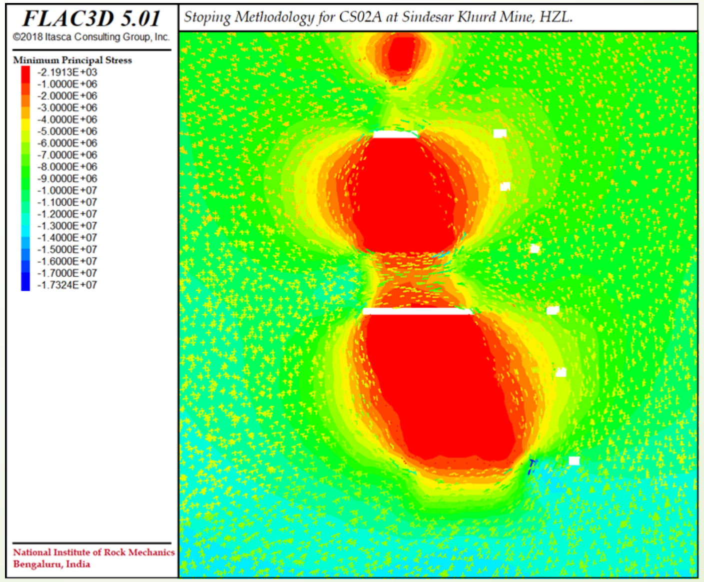
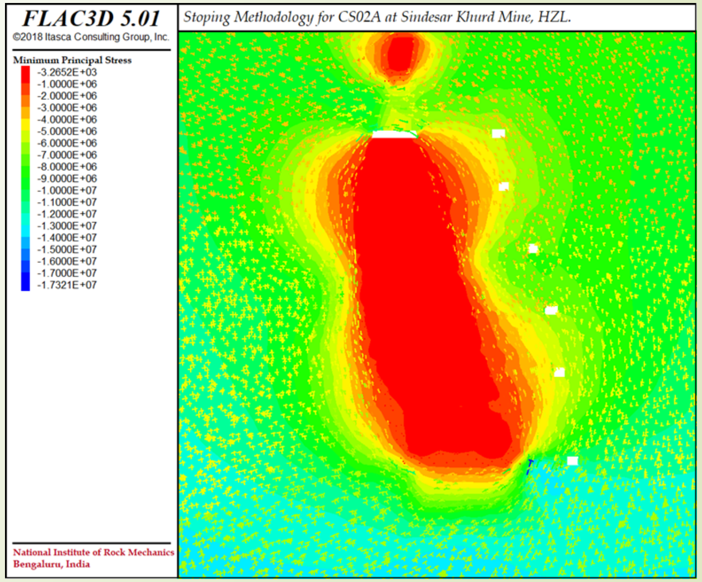


Case - IV

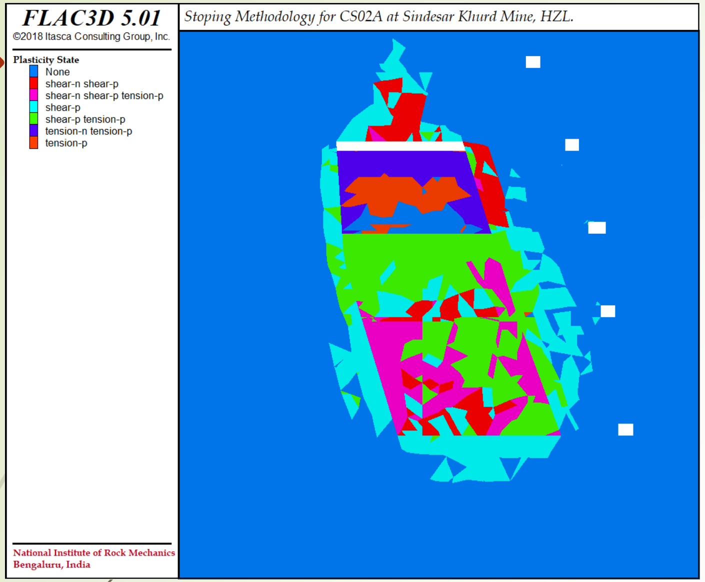


Case - V

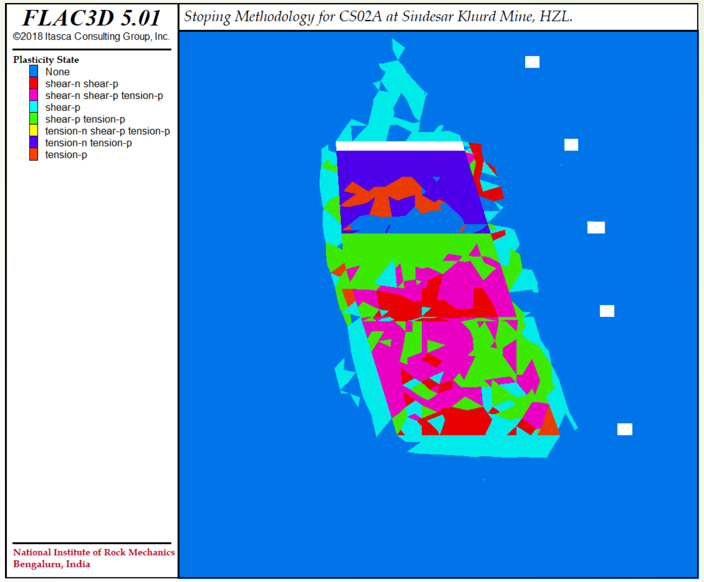


Case - VI

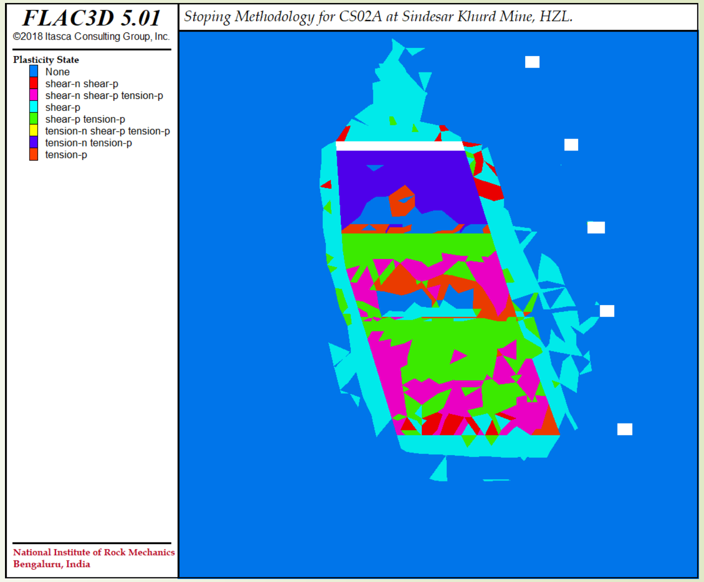
Results – Model State



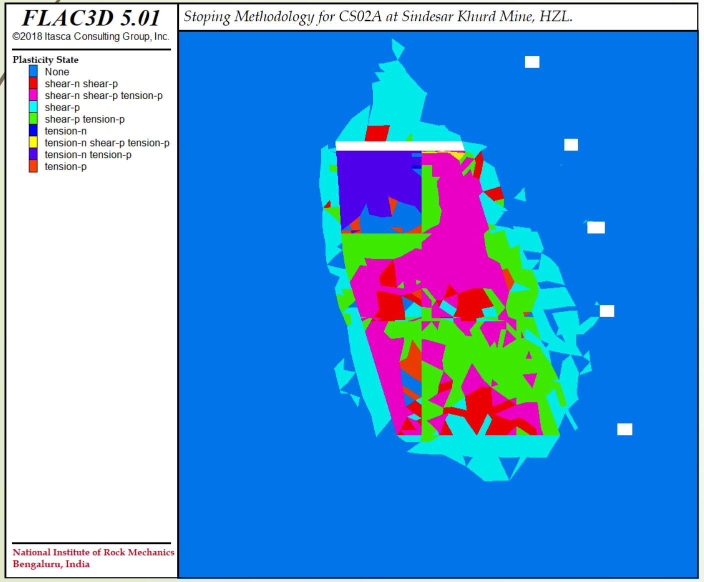
Case - I



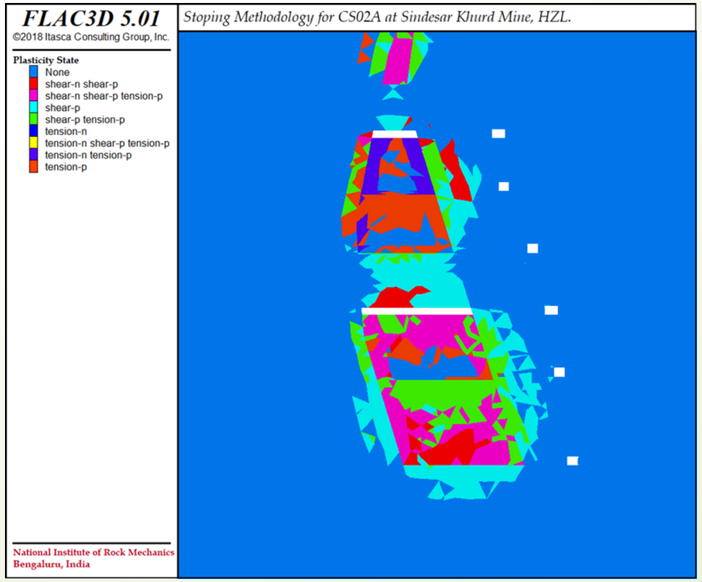
Case - II



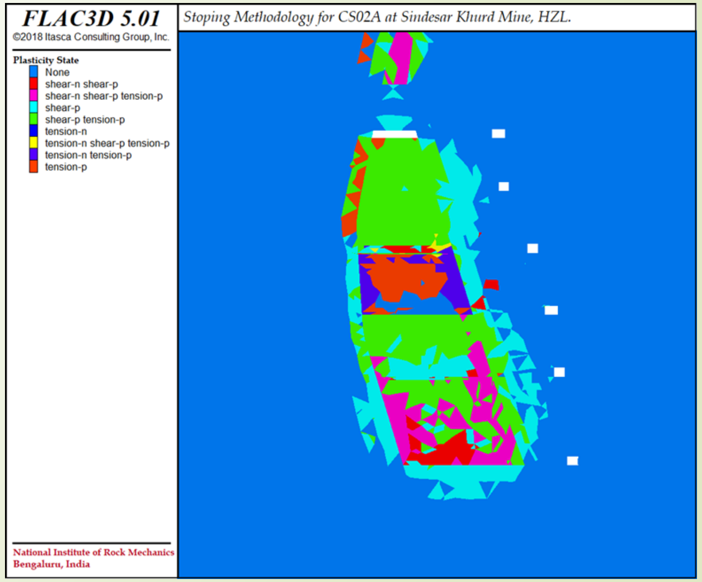
Case - III



Case - IV



Case - V



Case - VI

Conclusions

- Displacement magnitudes are relatively higher in Case 1 than that of Case 2. The magnitude of maximum principal stress is at par in both the cases. The destressed zone is larger in case 1, as indicated in minimum principal stress contours.
- Displacement magnitudes are at par in Case 3 and Case 4. In Case 4, the fill material in the eastern half is observed to be displaced slightly more. Maximum and minimum principal stress distributions patterns and their magnitudes are almost similar. While the influence of intermediate principal stresses marks the development of tensile zone in stope back in case 4.
- From Case 5, it is observed that during extraction of ore from lower part of secondary stope between -55 mRL and 30 mRL, followed by extraction of ore in the upper part, i.e. 65 mRL and 130 mRL, the temporary crown between 30 mRL and 65 mRL is stable. However, from case 6, it is observed that when the temporary crown is mined out at the end, there is a likelihood of failure of fill from the upper part as well as geological hangwall. This could result in posing instability issues while stoping of temporary crown in the secondary stopes. Post excavation of the temporary crown, stresses are getting concentrated in the abutment temporary crowns in the adjacent primary stopes.

Recommendations

- Based on the results and conclusions, the following recommendations are being made:
- For safe extraction of CS02A stope, stoping methodology as mentioned in Case 2 or Case 3 is recommended.
- Stoping sequence in all cases must be bottom up since there is a likelihood of failure in the temporary crown and hangwall, if the temporary crown is mined out at the end.
- The haulage drive must be developed in western side or geological footwall for safe mining of secondary stopes in C Block since the eastern haulage drives are observed to be unstable.
- Cable bolts shall be installed at stope back up to a depth of 10 m and up to 6 m depth at brow in a grid pattern of 2 m x 2 m.
- Installation of geotechnical instruments like MPBX and Stress Meters prior to start of stoping activity is prime most requirement in both crown and hangwall of every stope, to assess the stability during and post stoping.
- Ground vibrations shall be maintained below the permissible limits in all cases.


THANK
YOU
GRACIAS
ARIGATO
SHUKURIA
DANKSCHEEN
JUSPAXAR
TASHAKKUR ATU
YAQHANYELAY
SUKSAMA
EKHMET
GRAZIE
MEHRBANI
PALDIES
KOMAPSUMNIDA
MAAKE
BOLZÏN
MERCI
BÏYAN
SHUKRIA
TINGKI
GOZAIMASHITA
EFCHARISTO
SPASSIBO
SNACHALHUYA
NUHUN
CHALTU
WABEEJA
MAITEKA
HUI
YUSPAGARATAM
DHANYAVAAD
ANIHA
ATTO
MERSI
SPASIBO
DENKAUJA
NENACHALHYA
UNALCHEESH
GUI
HATUR
EKOJU
SIKOMO
MAKETAI
MINMONCHAR
SANCO
MERASTAWHY
GAEJTHO
LAH
TAVTAPUCH
MEDAWAGSE
AGUYJE
FAKAAUE
BAIIKA