Geotechnical Considerations for Early Pit Design Development and Life of Mine Optimization at Bozshakol Copper Mine

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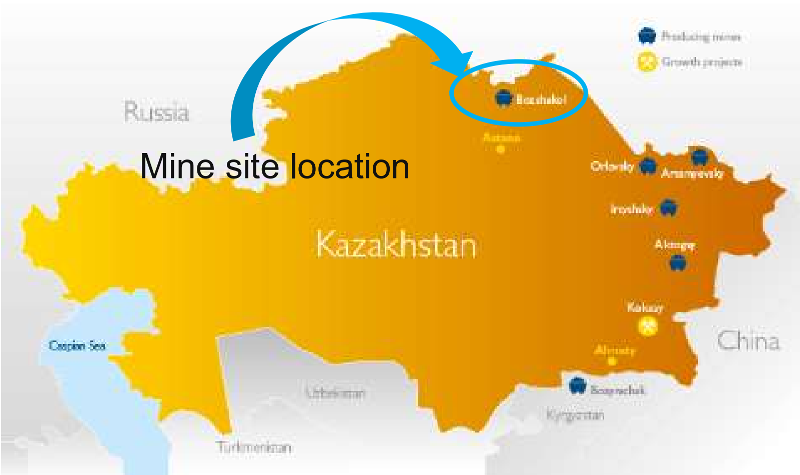
1. Introduction



Bozshakol deposit

Location :
- Ekibastuz, Pavlodar region, Republic of Kazakhstan

Copper Grade:
- Bozshakol mineral resources is 1,183 Mt with average grade of 0.33%

Processing Facilities:
- On-site facilities with 30 million tonnes annual ore processing

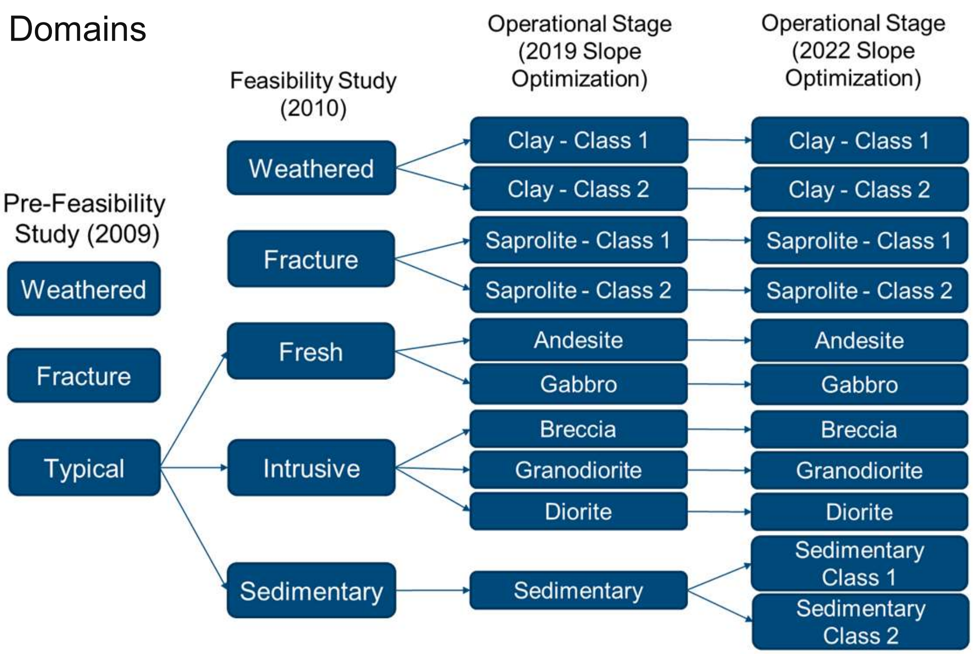
Life of mine :
- 40 years, commencing with the first production in 2016.

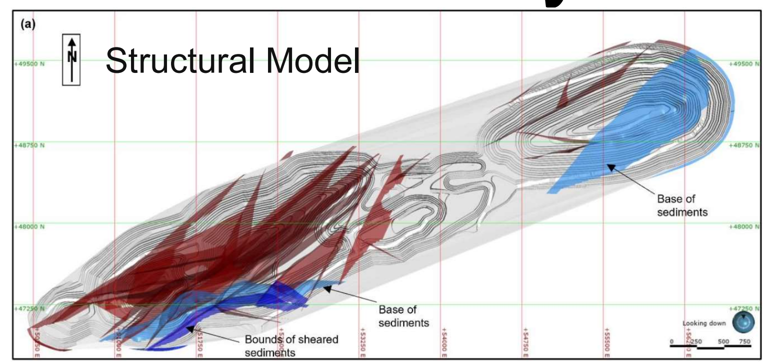
Current Pit depth:
- Approximately 200 m

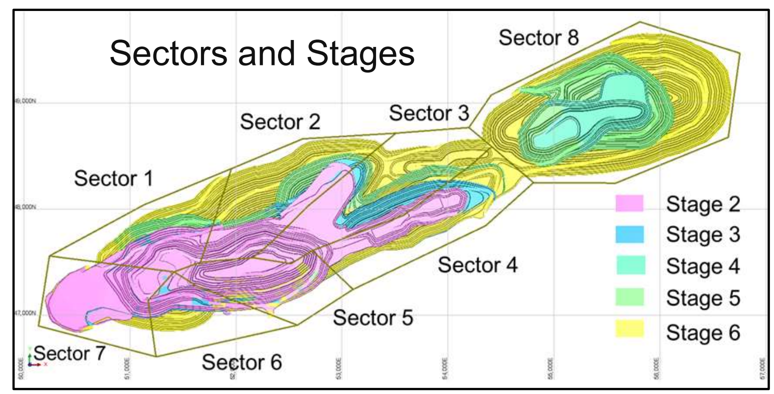
Dimensions:
- Length: 4.5 km (Northeast to Southwest)
- Width: 1.8 km (Southeast to Northwest)

Future Pit Slope Heights:
- Expected to reach 430 m

2. Reducing Geotechnical Uncertainty







Improving Geotechnical understanding:

- 21 DD holes in PFS+FS, additional 30 DD holes during operation stage, >2,000 lab test, Geotechnical face mapping and photogrammetry.
- Geotechnical domains based on rock mass and structural models.
- Introducing pit design sectors.
- Back-analysis of failures 3D and 2D models (Adiyansyah et al. 2023).
- Geotechnical block models : RQD, Hardness, BI, GBI.

3. Slope Stability Analysis and Optimization

Current slope performance :

- Inter-ramp and bench scale slope performances have been good on overall.
- Blasting practices continuously improving (Adiyansyah et al. 2023).
- Consistent bench retention for rock fall risk management.
- Slope failure risks managed by ground-based radar and prism monitoring.

Geotechnical review of Stage 3 as part of Life-of-Mine (LoM) using 3D slope stability analysis (Adiyansyah et al. 2023).

Analysis scenarios:

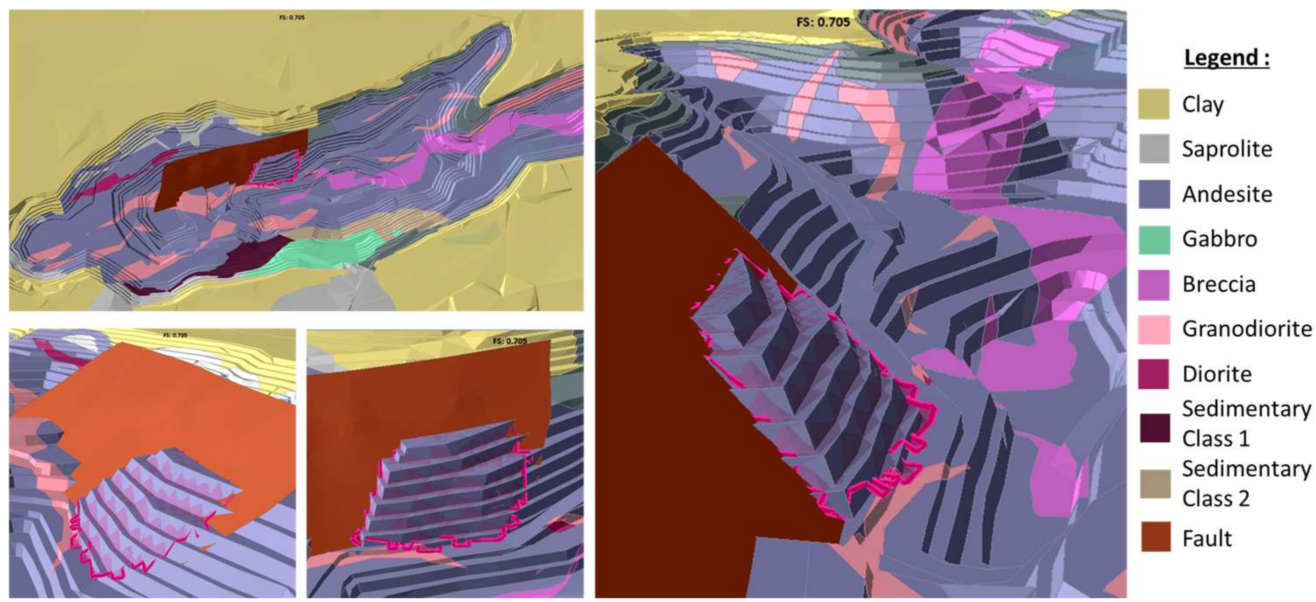
- Best estimate “most likely case”: MC model for Clay and Saprolite, GHB for Fresh domains, Anisotropic strength for Sedimentary. Blast damage factor D=0.
- Sensitivity analysis :
    - Pore pressure : Increased H_u coefficient for post-rainfall or snow melt condition.
    - Pore pressure : Various levels of reduced H_u through horizontal drain.
    - Reduced material strength using lower bound UCS or increased blast damage D=0.7.

3. Slope Stability Analysis and Optimization

Stage-3 design meets and exceeds DAC for best estimate except for a potential planar sliding mechanism.

- FoS<1.00 for an inter-ramp scale planar sliding failure mechanism on the lower north wall.
- FoS < 1.20 for two of the six localized multi-bench scale failure mechanisms within the Clay at the top of the slopes.

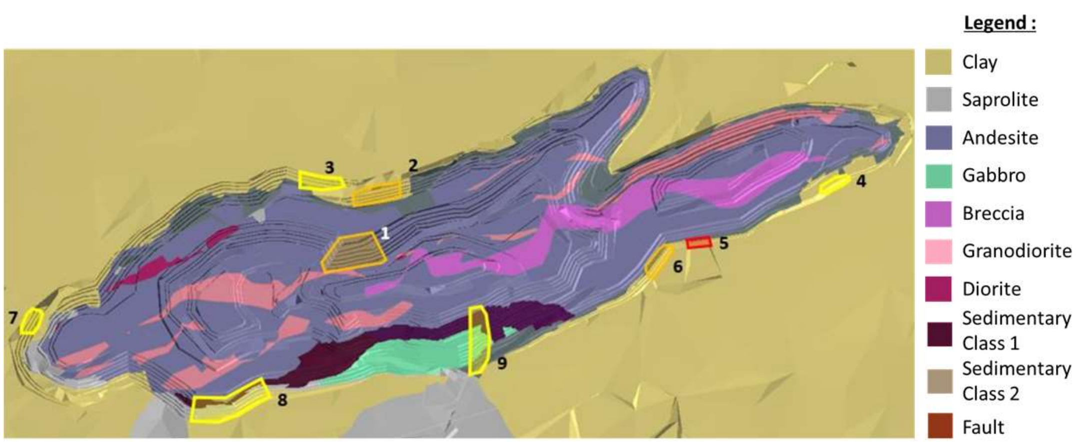
- FoS > 1.20 for all inter-ramp slopes below the Clay.
- FoS > 1.30 was identified for all overall slopes.



- *<u>Potential for steeper slopes may be possible provided that any rock fall risk associated with bench geometry can be managed.</u>*

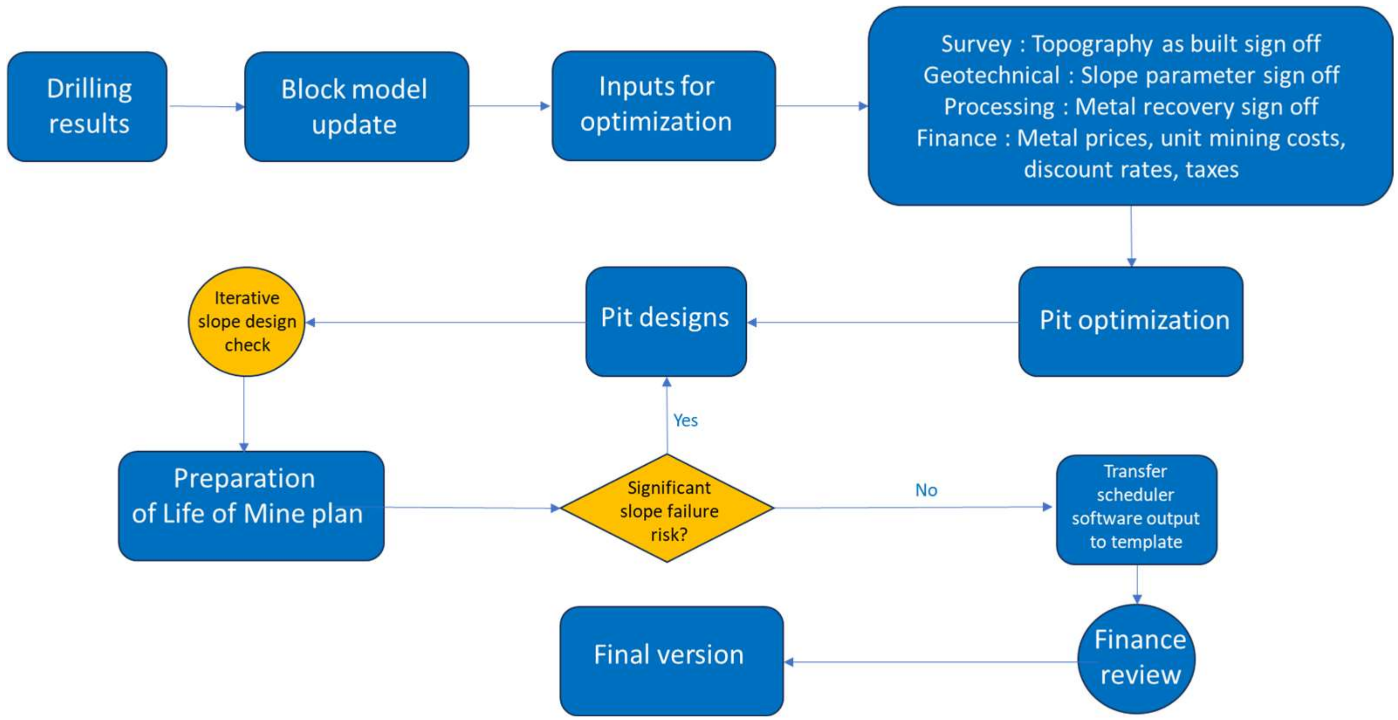
4. Geotechnical Risks and Control Measures

Risk area	Risk Description	Minimum Static FoS	FoS Type	Priority
1	Lower slope on North wall : Planar failure mechanisms on 160 - 40 bench driven by fault	0.70	3D Bishop	2
2	Central area North wall : shear failure through Clay	1.08	3D GLE	2
3	Central area north wall: shear failure through Clay on 230-190 bench	1.19	3D Bishop	3
4	South-east wall: shear failure through Clay at steep slope profile on 220-200 bench	1.14	3D Bishop	3
5	South wall: shear failure through Clay at steep slope profile on 230-200 bench	0.81	3D GLE	1
6	South wall: shear failure through Clay at steep slope profile on 230-200 bench	1.08	3D GLE	2
7	West wall: shear failure through Clay at steep slope profile on 230-200 bench	1.15	3D GLE	3
8	South-west wall: shear failure through Saprolite and highly altered Sediments at steep slope profile on 230-180 bench	1.13	3D Bishop	3
9	South wall: shear failure through Gabbro and Sediments involving two faults	1.15	3D Bishop	3



- The life-of-mine optimization for Stage 3 involves incremental slope steepening and specific risk reduction measures.
- The risk areas are prioritized for further investigation or remediation.
- Crucial role for stability : Pore pressure considerations, orientation and character of faults.
- Steeper angles are proposed for fresh rock, with a wide geotechnical berm for every 120 meters of vertical advance.
- Optimization measures aim to enhance safety and economic potential.

5. Mine Plan Interactions for Slope Optimization



Components required for slope optimization :

- Economical data (unit cost and metal price)
- Geological model (block model including mineral resources and reserves).
- Geotechnical input.

6. Key Findings

- Geotechnical level of confidence is increasing since PFS to operational stage in line with additional data obtained from various site investigations, laboratory test, and understanding of actual slope performance.
- Slope steeping as part of LoM optimization is permissible considering that following actions shall be implemented:
  - Major structure model – ongoing updates every 2 years or less.
  - Pore pressure management and slope depressurization including horizontal drilling supported by a network of >60 VWPs to measure effectiveness.
  - Monitoring and response protocols including sub-surface displacement monitoring such as TDR (time domain reflectometer) combined with existing near real time radar and prism monitoring with alarming and TARPs.
  - Geotechnical team resourcing including separating the Ground Control and Monitoring positions, and moving to a 24-7 monitoring, analysis, and response capability.
- The same approach for slope stability assessment should be carried out for further design push backs with optimized slope design parameters until end of life-of-mine stages.

Acknowledgements

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