

UNDERGROUND MINE SURFACE SUBSIDENCE EVALUATION AND CLOSURE

Mine Design, Operations & Closure Conference 2013



**CDM
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General Information

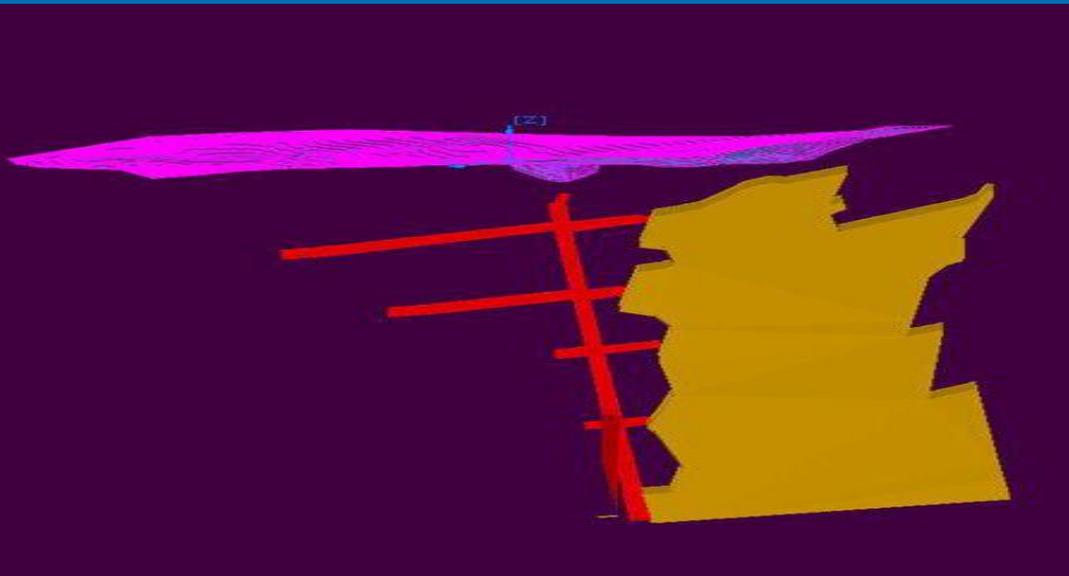
- Located in southwest Montana
- Underground mine
- Used a lower adit and light rail haul tunnel at the base of steeply dipping ore bodies
- Stopes extend nearly vertically in excess of 500 feet
- Part of an active subsidence monitoring and reclamation program
- Thin roofed areas
- Safety

Investigation Approach

- Digitize Historic Mine Maps
- Create a Vulcan 3-D Model of mine workings
- Survey (GPS) previously closed features that can be identified on Historic Mine Maps
- Survey subsidence area to be stabilized
- Adjust 3-D Model to tie in with surface survey data
- Perform Ground Penetrating Radar (GPR) survey to identify possible near surface voids
- Develop closure work plan to safely stabilize features

DC-24

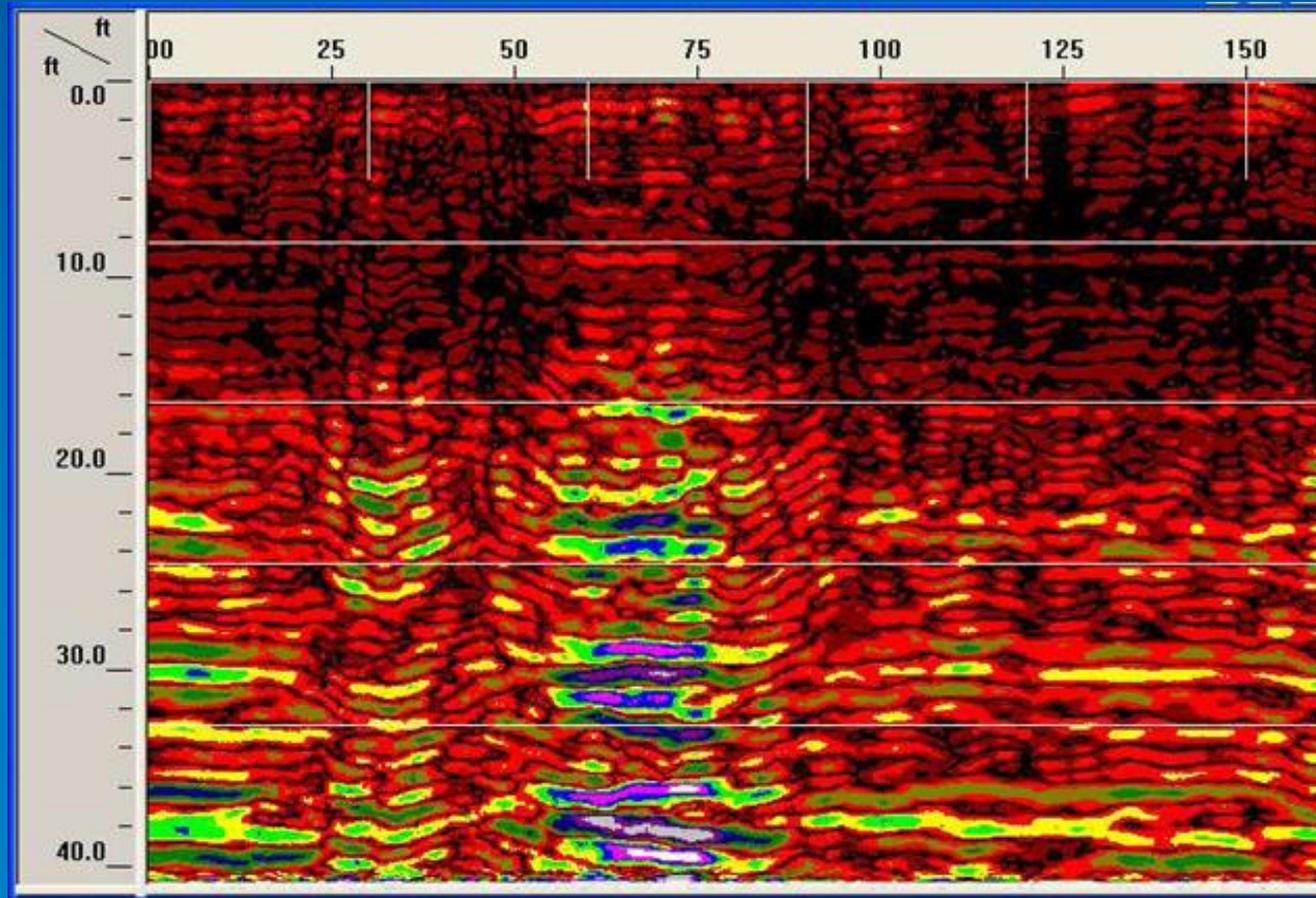
- Subsidence found to be in the location of a vent raise shown on historic mine maps



DC-24 Safety

- GPR Survey
 - Avoid working from south side of feature with heavy equipment
- Daily site inspection
- Daily control points monitoring
- Highwall
- Spotter
- Fire
- Dust Control

DC-24 GPR Survey

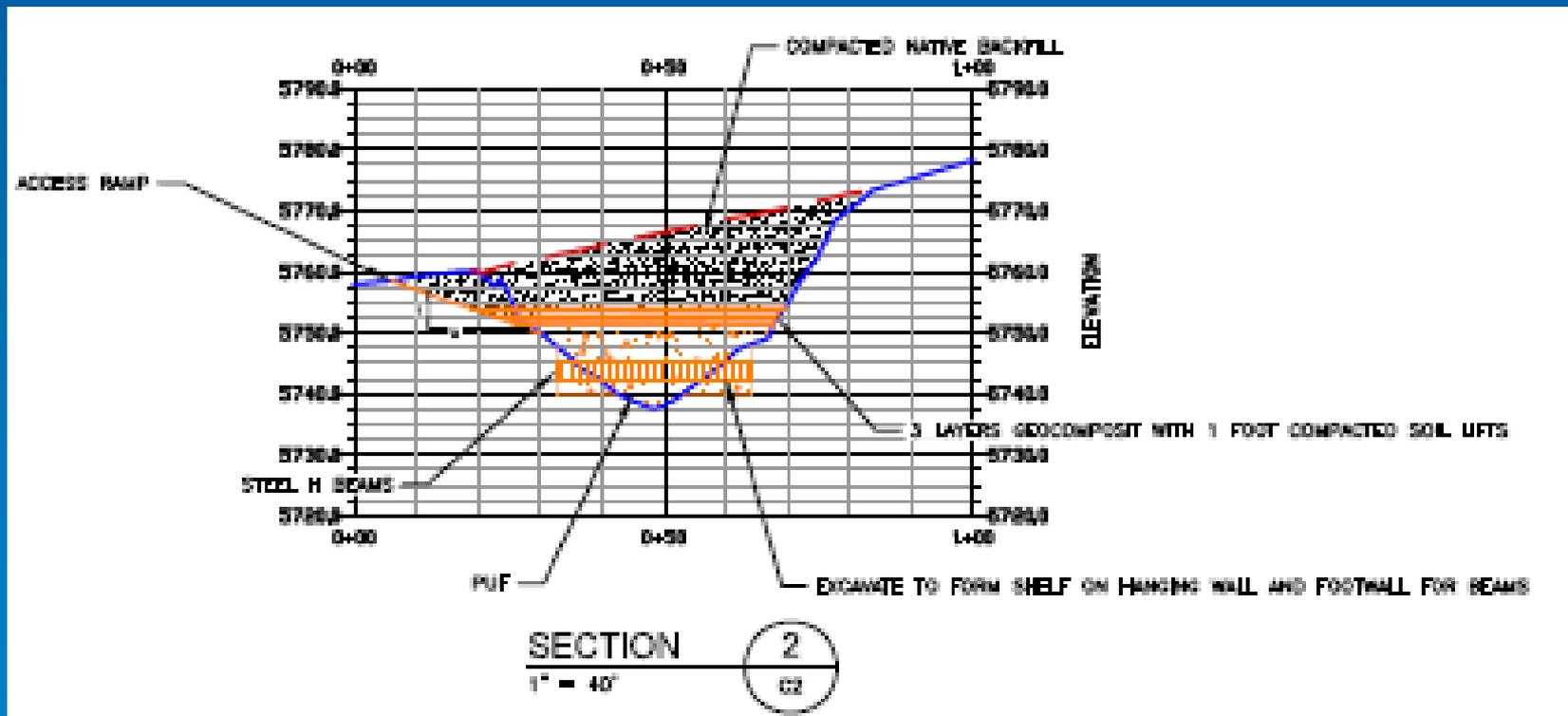


DC-24 Closure

- Preliminary design developed
 - Remove loose material from Hanging wall, Footwall and base of subsidence.
 - Steel reinforced Polyurethane Foam Plug
 - Structural Backfill w/ drainage
 - Grade to drain
 - Install runoff controls



DC-24 Closure



DC-24 Closure

- Remove loose materials –
 - Competent bedrock not found during excavation
 - Subsidence expanded during excavation
 - Plan modified to lengthen steel beams
 - Steel placed on undisturbed soil on footwall and hard clay layer on hanging wall



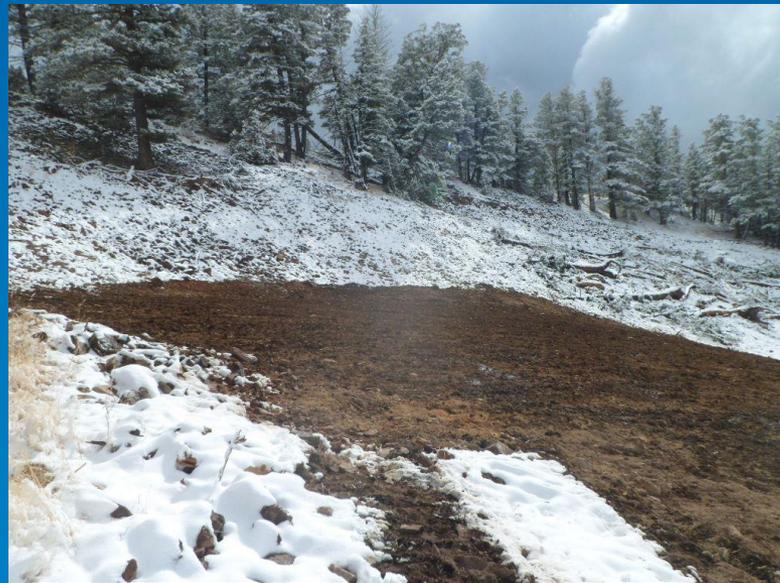
DC-24 Closure

- Polyurethane (PUF) Plug installation initiated
- Steel Beams and cross members installed w/ cathodic protection
- PUF Plug completed



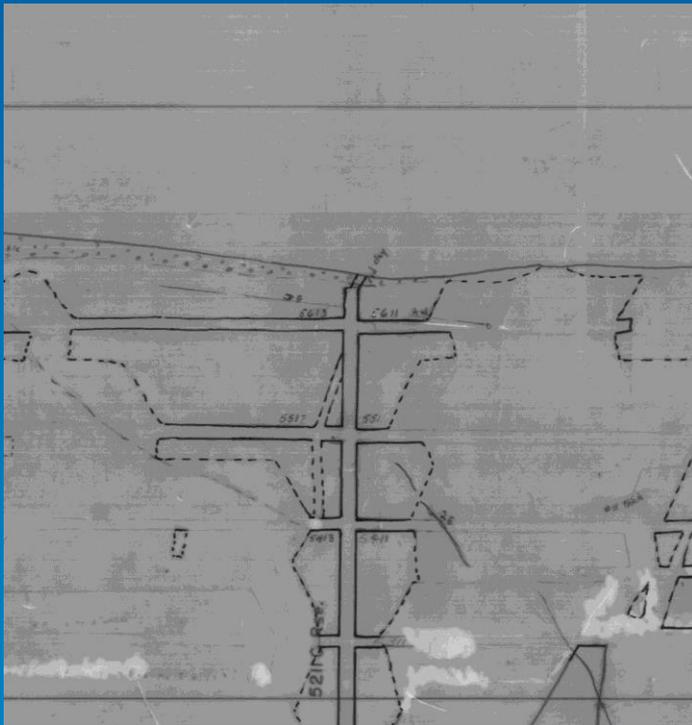
DC-24 Closure

- Structural backfill w/ drainage
 - Three layers of geogrid/geotextile installed between soil lifts
- Backfilled, compacted, graded, water management



DC-25

- Thought to be caused by a previously collapsed stope that is continuing to subside



DC-25 Safety

- GPR Survey & 3-D Model indicated near surface voids
- Work perpendicular to strike of ore
- Work from footwall side of feature
- Daily site Inspections
- Daily control point monitoring for movement
- Utilize spotter

DC-25 Closure

- Salvage and stockpile topsoil
- Partially backfilled feature and graded to drain
- Installed 2 layers of geogrid/geotextile
- Steep slope to east side of feature graded over subsidence



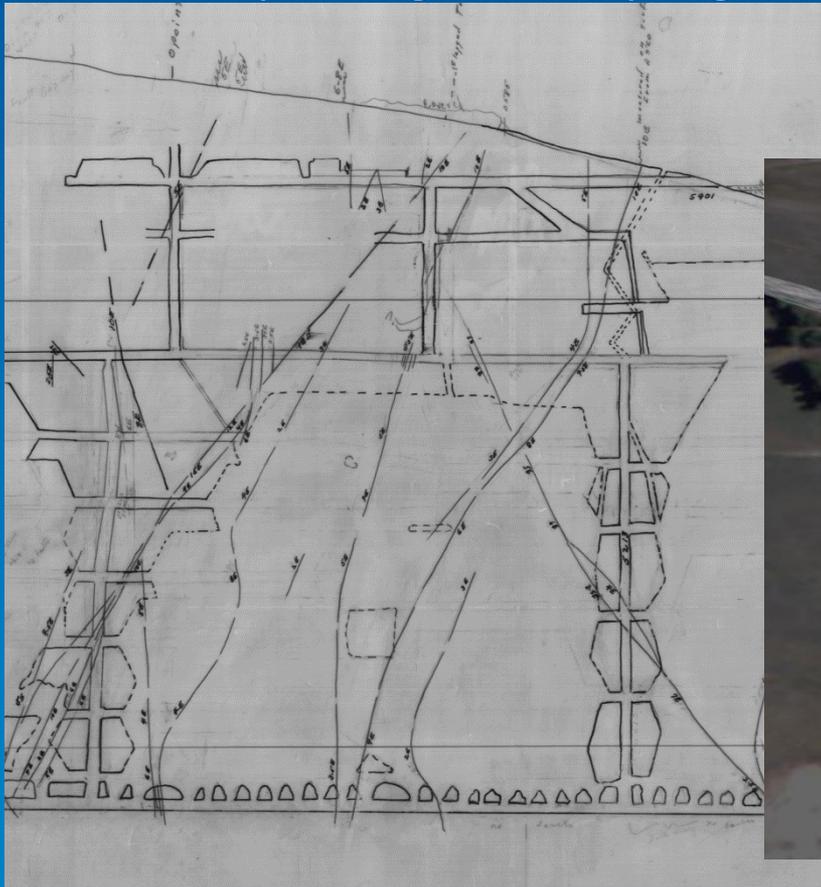
DC-25 Closure

- Stormwater Management
- Reclamation



DC-16

- Small opening developing through entrance of closed portal



DC-16 Safety

- GPR survey indicated voids through closed portal entrance
- Competent ground identified to west of feature
- Work conducted from west side of feature



DC-16 Closure

- Removed unconsolidated material from feature
- Confirmed vertical vent raise going down to lower workings



DC-16 Closure

- Installed PUF Plug (Approximately 10 foot thick)



DC-16 Closure

- Backfilled
- Stormwater Management



Ongoing Monitoring

- Set control points away from mine workings
- Set pins around subsidence area
- Yearly survey to monitor for signs of ground movement
- Visual inspections for indications of ground movement



Predicting Subsidence

- Develop accurate 3-D model of mine workings
- Identify thin roof areas
- Identify areas where stormwater can flow into mine workings
- Visual signs of ground movement



Developing Engineered Solutions

- Versatility is paramount (no one size fits all)
- Combination of various solutions may be necessary
- Solution must remain fluid through construction
- Design build approach is beneficial
- In cases with narrow vents, deep shafts, or areas where access is difficult, PUF is often an appropriate solution



Developing Engineered Solutions

- Blasting can be an effective solution if workings can be understood and work can be completed safely
- Can cause additional issues



Developing Engineer Solutions

- Bat Gates, Fencing and Monolithic Concrete Slabs can be effective



Developing Engineer Solutions

- Earthen backfill can be effective if subsurface volumes are understood and can be managed.



Conclusion

- Historical record-keeping and documentation of past reclamation / closure activities is very important
- Vulcan 3-D model
 - Shows relationship between surface and mine workings
 - Identify high risk areas with thin and weak ground cover (future subsidence)
 - Shows old workings and known geology
 - Needs accurate surface topography
 - Incorporate drill hole and geological data
- Yearly inspections and benchmark surveying should be completed yearly
- Variety of engineered solutions may be needed for permanent closure
- Design Build Approach
- Stormwater Controls

Questions

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