Closure of Remote Historic Underground Mines in Desert Environments

James A. Cremeens  Agapito Associates, Inc.
Michael H. Rauschkolb  U.S. Borax, Inc.
- Geotechnical solutions were developed for closure of two historic underground borate mines in the deserts of California
- The Old Borate mining district located in the Mojave Desert near Barstow California
  - Mined from 1890 to 1907
- The Lila C. Mine near Death Valley California
  - Mined from 1907 to 1916 and 1920 to 1926
Location of the Old Borate and Lila C. Mine Sites

CALIFORNIA

San Francisco

Death Valley

San Bernardino

Los Angeles
Big Borate Canyon
Big Borate Canyon
post-1898
Haulage Adit
Dugout Dwelling
Underground at Old Borate
(Circa 1902—from Reynolds 1999)
Closure Criteria

• Prevent public access
• Protect wildlife
• Minimize impact to fragile desert landscape
• Assure environmental compatibility
• Optimize use of native materials
Wildlife Protection

- Conducted by bat and desert tortoise specialists
- Daytime internal examination and night bat surveys with night vision equipment and ultrasonic detectors
- No tortoise sign found within mines
- Bats or bat sign found in most of the mine openings
- Mine openings fenced to allow bat exit but not re-entry
Pre-Construction Design

- ADITS
  - Collapse and Regrade
  - Polyurethane Foam
- SHAFTS and STOPES
  - Pre-Cast Concrete Panel Caps
Pre-cast Concrete Panel Design

Original Ground

Final Grade (3H:1V)

Excavation (1.5H:1V)

Shaft Opening

Precast Concrete Panels

Backfill with Mine Waste Rock (optional)

Survey Monument

Armor Finished Slope with Cobbles and Boulders

Surficial Material Backfill

Extremely Weathered Siltstone

Unweathered Siltstone

Prepare Smooth Foundation Surface and Shim Such That Panel Edges are Flush and Panels are Coplanar

Panel Foundation

Panel Abutment Joint

12" Typ.

48" Typ.

48" Typ.

2L

Surficial Material Backfill

Shaft Opening Backfill with Mine Waste Rock (optional)
Field Conditions

- Strength of weak siltstone and claystone did not increase with depth
  - Low bearing capacity
  - Foundation could be easily eroded
  - Ground caved and grew laterally with excavation

- Excavated mine openings were larger than surface expression
  - Large spans for pre-cast concrete panels
  - Increased number of concrete panels
  - Would have required steel beam support for large spans
Final Design

- SHAFTS and STOPES
  - Boulder Plug
- ADITS
  - Collapse and Regrade with Boulder Plug
  - Polyurethane foam
Components of a Typical Boulder Plug Closure

- Original Ground
- Surficial Material Backfill
- Survey Monument
- Excavation (1H:2V)
- Boulder Plug
- Unweathered Siltstone
- Extremely Weathered Siltstone
- Final Grade
- Surficial Material Backfill
- Original Ground
- Extensively Weathered Siltstone
- Unweathered Siltstone
- Final Grade
Typical Adit Boulder Plug Closure

- Survey Monument
- Original Ground
- Adit Portal
- Excavation (1.5H:1V) (Collapse)
- Boulder Backfill
- Surficial Material Backfill
- Regraded to Original Slope or Flatter

Adit Portal
Typical Boulder Plug Placement Sequence

Placing Initial Boulders

Completed Boulder Plug

AGAPITO ASSOCIATES, INC.
Consulting Engineers
Typical Boulder Plug Placement Sequence

Beginning Backfill and Regrade

Placing Final Soil Cover
Summary of Old Borate Closure

- 120 mine openings closed in 5-week period
- Boulder plugs satisfied design criteria
- Closure costs were significantly reduced by using native materials
- Lower unit costs = more mine openings closed
Lila C. Mine Site
— Circa 1907
Main Haulage Level of the Lila C. Mine
—Circa 1910
Stope at Lila C.
Decline shaft at Lila C.
Open Stope at Lila C.

U.S. Borax, Lila C. Mine
July, 2000
No. 22a-c
pre-closure
Wildlife Protection

• Conducted by bat and desert tortoise specialists

• No tortoise sign found within mines

• Surveys revealed four species of bats in the mines

• Two bat “Species of Special Concern” found

• Bat accessible designs were included in closure
Bat Accessible Closures

- Bat gates and cupolas designed by specialty contractor to protect bat access, preserve ventilation, and maintain temperature
- Underground surveys conducted to optimize bat accessible design
Closure Design

• SHAFTS and STOPES
  • Rock Mattress – AAI innovation

• ADITS
  • Collapse and Regrade with Boulder Plug
  • Polyurethane foam
Rock Mattress Excavation and Construction of a Daylighted Stope Closure
Rock Mattress Construction for a Daylighted Slope

- Top Layer Gabions
- Bottom Layer Gabions
- Existing Open Stope
- Bottom and Top Layer Gabions In Place
Mattress Construction for a Daylighted Stope

a) Pre-construction

b) Grading Hanging Wall
Rock Construction for a Daylighted Stope

c) Wheel Roll Compaction

d) Gabion Construction
Rock Construction for a Daylighted Stope

e) Filling Gabions with Native Rock

f) Backfilling Over Gabion Rock Mattress
Rock Construction for a Daylighted Stope

- g) Partially Backfilled Rock Mattress
- h) Final Grade and Armored Slope
Rock Construction for a Shaft Closure

a) Shaft after Surface Preparation for Rock Mattress
Rock Construction for a Shaft Closure

b) First Layer of Gabions of Shaft
Rock Construction for a Shaft Closure

c) First and Second Layers of Rock-filled Gabions—Completed Rock Mattress at Shaft
Rock Construction for a Shaft Closure

d) “Load Test” on a Rock Mattress at Shaft
Rock Construction for a Shaft Closure

e) Backfill over Rock Mattress
Typical Foam Seal Construction

a) Preparing Backing Lattice

b) Applying Foam

c) Completed Foam Application without Backfill
Bat Gate
Construction and Final Configuration of Bat Cupola

a) Landing Ring and First Course Concrete Pipe in Place

b) Completed/Backfilled Shaft Extension And Bat Cupola
### Cost Comparison (USD-2000)

- Gabion Rock Mattress with concrete: $21,920
- Plastic Grid: $21,712
- Foam Plug: $20,890
- Gabion Rock Mattress: $18,880
Thank-You