



TAKING SURFACE QUARRY OPERATIONS UNDERGROUND

SME PITTSBURGH SECTION SPRING SEMINAR SERIES

By: Peter Christensen
peter.christensen@respec.com



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TODAY'S REALITY



SEEMINGLY UNAWARE of the amount of sand, gravel, aggregate, and cement they consume, people are increasingly opposed to quarry development and urban sprawl crowds quarries while demanding their products.



ONE SENIOR INDUSTRY OFFICIAL observed that state and federal permitting is difficult, but manageable; however, local action and approvals are full of uncertainty.



ENVIRONMENTAL GROUPS, local activists with the power of internet communication, and social media are opposing quarry development now more than ever.

Gravel quarries, Kerr mining still a hot issue

DEEMED

Snow Camp residents
gravel construction
9th November 2018

No Quarry

Quarry Permit Denied

Commissioners deny quarry permit after 'overwhelming' opposition

Quarry yard signs created by citizens groups in South Tecumseh Road neighborhood near High School approved expanded limit intensifying opposition from area residents
Audrey Hackett
Published: September 21, 2019
No Comments

Magruder quarry opposition in Sunrise
By Janet Dabbs Aug 15, 2013

SUNRISE BEACH, Mo. — Another rezoning request for a monolithic quarry from the Sunrise Beach Board of Commissioners has been rejected by the board of commissioners with a unanimous vote squelching the company's expansion plans.
Proposed Cemex Quarry Under Fire from California Officials

Created: Thursday, 17 January 2019
Published: Thursday, 17 January 2019
1

Published: Saturday, 18 July 2015 23:30 Written by Rock Products News

Washington Quarry Faces Opposition



OPTIONS ???

OPTION NO. 1

Abandon the market



May affect downstream business

OPTION NO. 2

Transport sand, gravel,
and aggregates from
sources farther away



Depending on logistics, transportation can be competitive



Assumes you can get permits "farther away" or transportation will not be opposed

EVEN TRANSLOADING FACILITIES ARE TOUGH

- › Near Denver, Martin Marietta faced strong opposition to opening a facility (Rock & Rail) to accept aggregate railed from their Wyoming quarry.

We are railing aggregate from Wyoming to the front range of the ROCKY Mountains!

/ After a 3-year battle, the facility opened in 2018 and faced ongoing opposition by local opponents.

- › The Cemex Lyons cement plant no longer quarries raw materials locally but trucks them from as far as Wyoming and local opposition continues to try and force the plant to close.

WEST COAST EXAMPLE

Why builders of big L.A. projects are making concrete with gravel and sand shipped from Canada

By JAMES RUFUS KOREN NOV 04, 2017 | 6:00 AM



Conveyor belts stretching more than a mile from the Orca quarry on Vancouver Island in Canada carry gravel and sand to a ship off the coast of Port McNeil. (Polaris Materials)

“Yet thanks to a combination of materials science, cheap ocean shipping and, some argue, NIMBYism, today’s industrial concrete mixers are often filled with imported rock and sand.”

“It’s not that California doesn’t have enough sand and gravel. But as development has sprawled, quarries or potential quarry sites that were once in sparsely populated areas are *now surrounded by people*— who don’t want the attendant noise, pollution and truck traffic.”

WHAT ABOUT GOING UNDERGROUND?

OPTION NO. 3 Going underground



Continues life at existing industrial facility
// Although still expect opposition

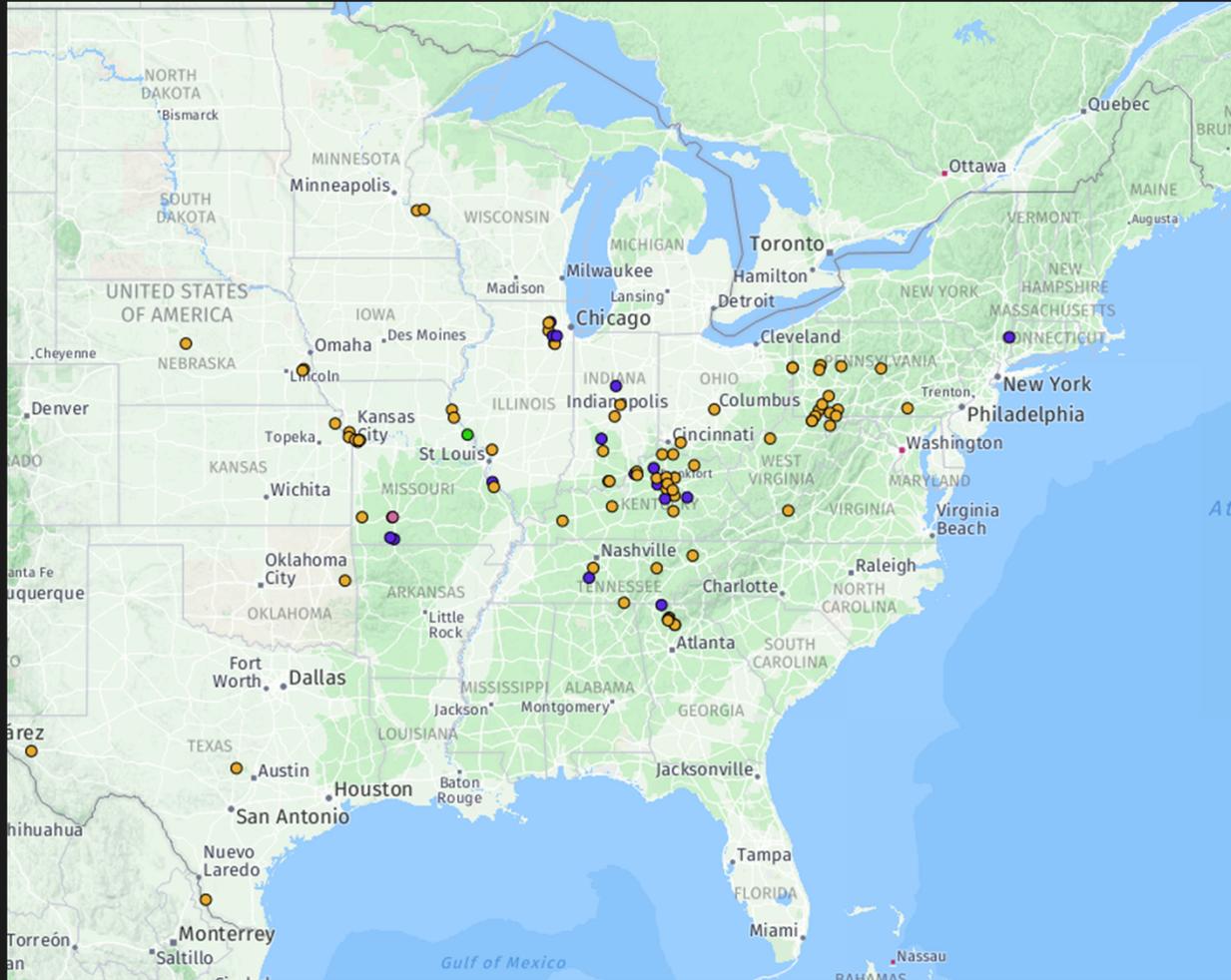


Reduces some of the impacts of a surface facility



Can be a competitive option if the geology extends deeper than the surface can access within existing permit area

UNDERGROUNDS OPERATIONS ARE WIDESPREAD



**2022 MSHA DATA
INDICATES 98 ACTIVE
UNDERGROUND STONE MINES**

Respec is working on aware of several more currently at different stages of evaluation and development

WHAT DO I NEED TO KNOW?

PRIMARY TECHNICAL RISK QUESTIONS

1

Does the geology extend/exist at depth?

2

Is the geology structure simple (minimal faults)?

3

What are the rock geotechnical characteristics?

4

Are there groundwater/gas considerations?

If there are no obvious fatal flaws in these areas, evaluating a practical mine design can follow.

GEOLOGY

OBJECTIVE

Sound geologic model representing the deposit in 3D including rock quality

- › If insufficient data exist, drilling is required.
- › Faulting and structure must be understood because the impacts can be more severe than in a surface quarry.
- › Geology investigations need to consider target limestone or other formation and adjacent layers.

GEOTECHNICAL

Geotechnical stability is different but equally or even more important underground.

- › **Characterize the limestone/rock being mined, as well as adjacent layers possibly forming roof and floor of openings.**
- › **Areas of significant in situ stress need to be identified.**
- › **Geotechnical analysis will define the following:**
 - / Size of openings and pillars (rock left behind),
 - / Preferred orientation of roadways,
 - / Roof and rib support required,
 - / Depth/barrier constraints,
 - / Subsidence constraints if required (possibly very important if in developing urban areas).

GROUNDWATER (HYDROGEOLOGY) AND GAS

Impacts of groundwater can be more disruptive in underground workings. Characterization will include the following:

- › **Water-bearing characteristics of different layers.**
- › **Expected inflow rates determines water management/pumping capacity.**
- › **Permit issues, including groundwater drawdown/impacts to wells and possibly quality (treatment).**
- › **Gas generally not a significant risk in stone mines, but it should not be summarily dismissed. Know the regional geology!**

WHAT OTHER SOME OTHER FACTORS?

OTHER RISK CONSIDERATIONS

1

Ownership of the
resource?

2

Zoning/Land use?

3

Permitting
requirements?

4

Infrastructure /
Utilities

In many cases, although there is an existing quarry,
these aspects may **NOT** simply "transfer" or be adequate

MINE DESIGN

If there are no red flags, the next step is mine design considering these features and addressing key areas of:

- › Access and logistics
- › Mining method and equipment
- › Material transportation
- › Ventilation.

The design is within an overarching framework of ensuring safe operations, achieving safety and environmental regulatory compliance, and maintaining community relations.

ACCESS AND LOGISTICS

How will you access the underground area and get miners and materials in/out?

- › From an existing pit, an adit can often be developed to minimize development to access the target zone.
- › If no suitable access from the existing pit, decline or slope tunnels can be developed from the surface; a boxcut could be used.
- › Shafts may be required for access. These have less commonly been used for this purpose in US stone mines, but mines are looking deeper.

MINING METHOD

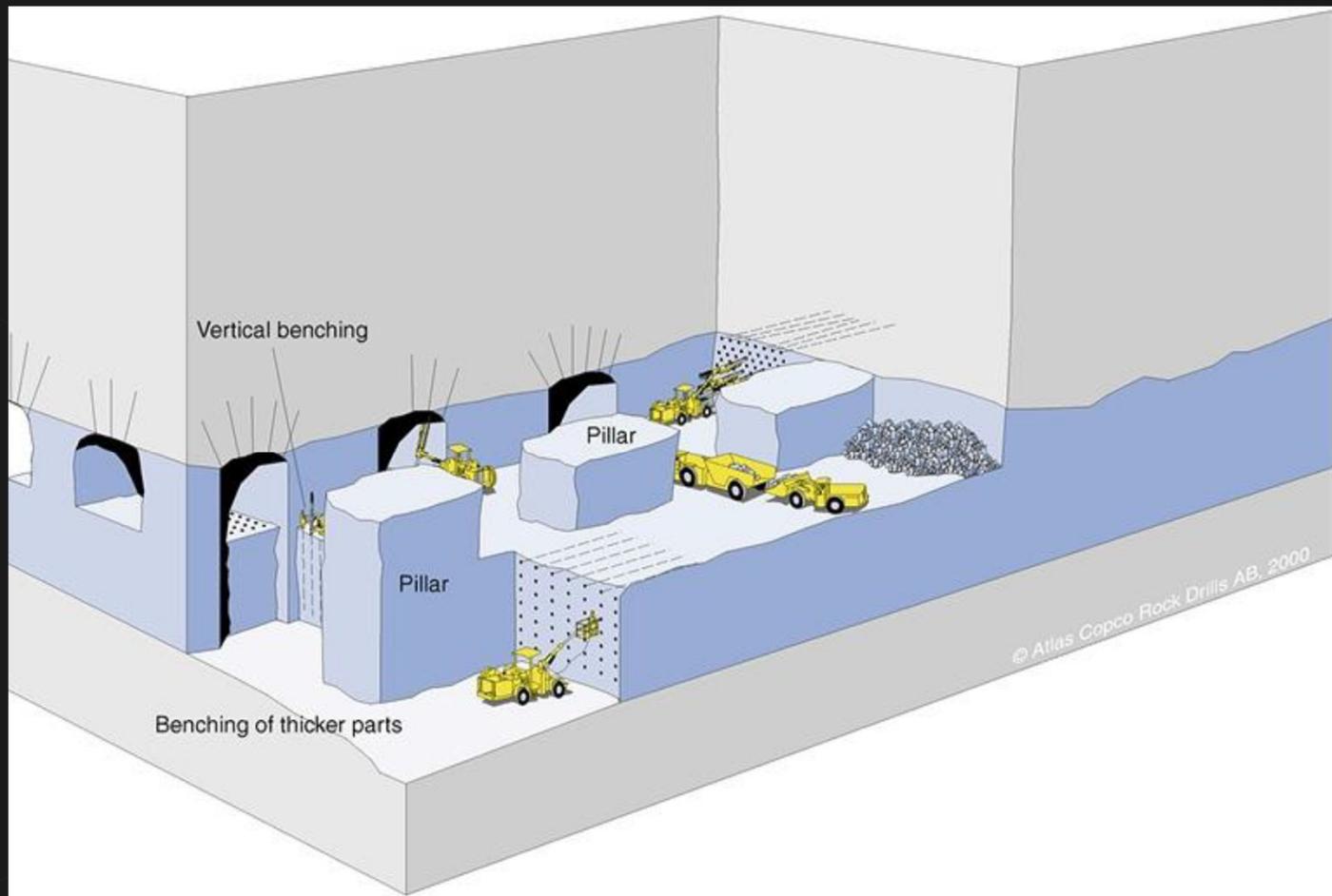
Factors that will affect the mining method include:

- › **Thickness of the limestone/rock formation**
- › **Dip of the formation**
- › **Geotechnical factors - strength of the target rock and adjacent layers**
- › **Required production rate.**

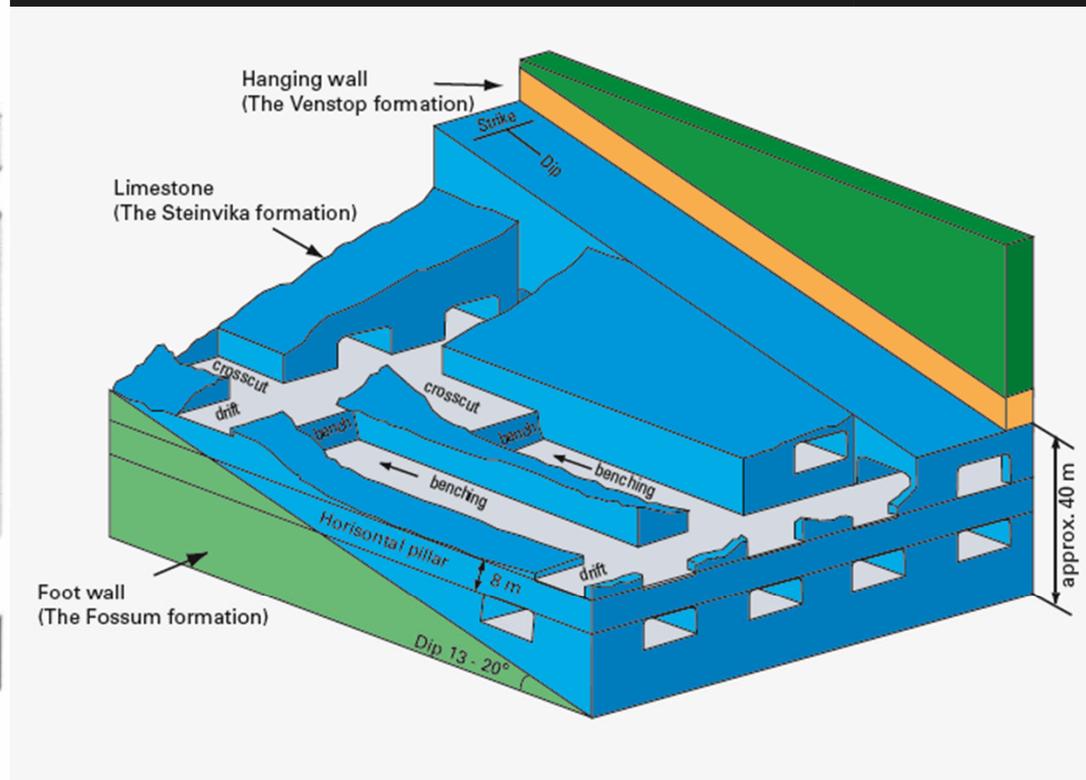
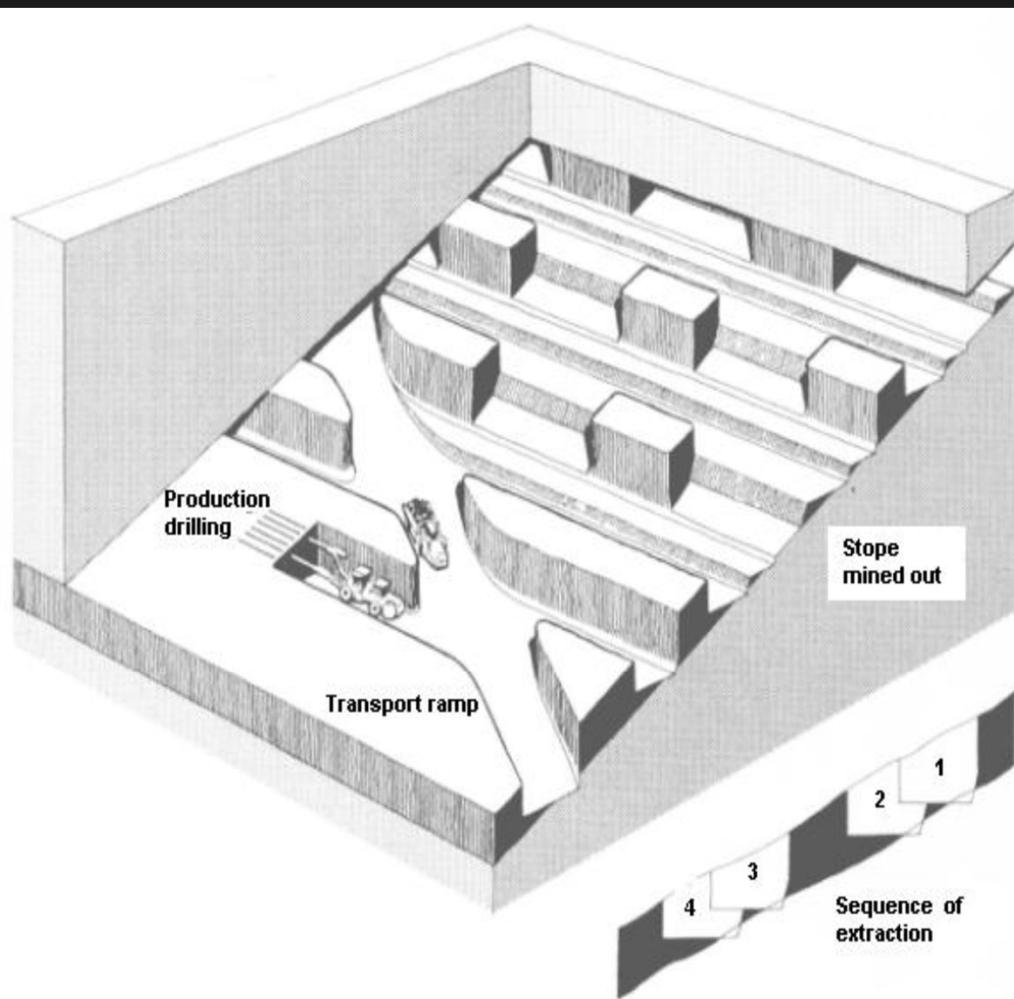
Mining methods are mostly variations of room and pillar, but stoping methods may be appropriate in thick deposits.

The height of the openings can be substantial with thickness up to 100 ft compared to coal mines that rarely exceeding 15 ft.

MINING METHOD ROOM AND PILLAR (FLAT)



MINING METHOD ROOM AND PILLAR (STEEPER)



Room and pillar with benching at Dalen mine, Norway.

EQUIPMENT

Because of large underground openings, equipment can include both familiar surface units and underground specific units:

- › Blasting typically involves “jumbos” with drill rigs on articulating booms.
- › Rigid and ADT trucks, wheel loaders, and even graders are commonly used.
- › Scaling equipment is used to reach high roofs and bring down loose rock.
- › Roof support or reinforcement typically involves a bolting machine that drills holes and then installs bolts.
- › Transportation usually in slightly modified pick-up trucks.

EQUIPMENT DRILLING / BOLTING

Twin Boom Drill Jumbo



Roof Bolter



Single Boom Drill Jumbo



EQUIPMENT BLASTING / SCALING



ANFO Explosive Loader

Cutter Scaler



Hammer Scaler

EQUIPMENT LOADING / HAULING

Underground Specific LHD



Conventional Surface Wheel Loader



EQUIPMENT LOADING / HAULING

Typical Surface Rigid Frame Truck



Typical Surface ADT



Underground Specific Truck



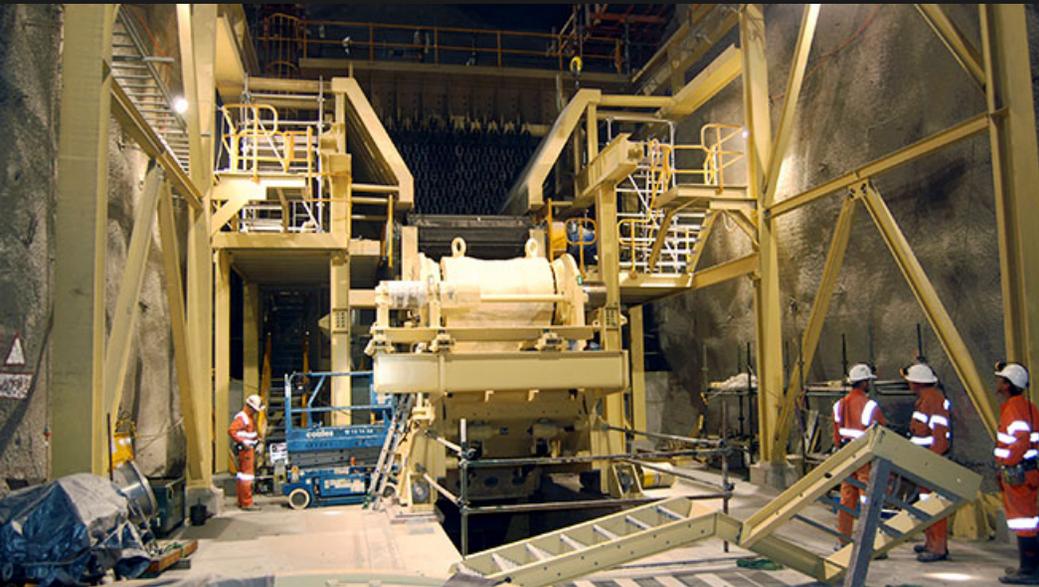
MATERIAL TRANSPORTATION

Various options exist for transporting mined stone to the surface. Most common is either truck haulage to the surface or conveyor belt. Deciding factors include:

- › Depth to the production level
- › Number of production levels
- › Production capacity

A combination of truck and conveyor may also be used for hauling to the underground crusher/conveyor location and between levels.

MATERIAL TRANSPORTATION



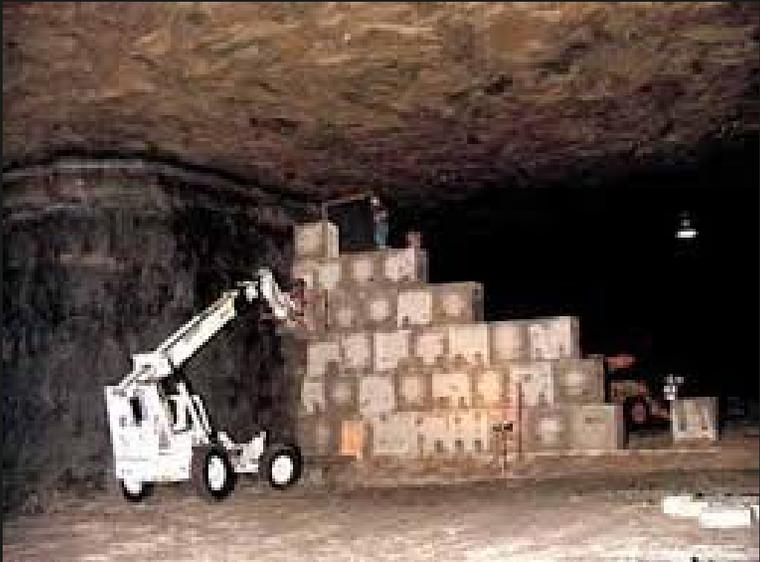
VENTILATION

Ventilation air flow is established by fans, including main fans that push or pull air from the mine and local area fans (booster or auxiliary) that direct air in zones and work areas of the mine.

Main fans may be installed as part of the mine access adit or slope or with a dedicated ventilation shaft.

A circuit to control air flow is created by "closing off" selected openings with "stoppings" (sometimes solid steel or concrete structures), but often in large stone mine openings, a synthetic curtain is used.

VENTILATION



WHAT WILL GOING UNDERGROUND COST

Costs can often be quite competitive with surface operations because of the following:

- › Similar sized production equipment is often used
- › Conveyors (if used) will have similar operational costs
- › Drill and blast costs may be slightly higher
- › Roof support and ventilation are additional costs
- › Mining little waste rock can compensate some of the higher costs

CAPITAL COSTS

The initial costs to develop and set up the underground operation will include:

- › Access, including emergency egress equipment
- › Ventilation
- › Underground primary crusher
- › Underground electrical
- › Mining equipment
- › Underground water management

CAPITAL COSTS – ACCESS

- › Direct access costs from a pit wall into stone will be close to the typical mining cost.
- › Box cut can reduce slope length.
- › Slope size should be adequate for largest projected underground mining equipment.
- › Slope access will depend on size and whether a conveyor is installed. Costs for a single 20-ft x 22-ft opening with conveyor may range from \$3,000–\$4,000/ft.
- › Twin slope access may add 50–60% (no conveyor in the second entry).
- › Other items may include surface area civil works, portal canopy structures, pit wall reinforcement, and utility hookups (underground likely will use more electricity than surface quarry).

CAPITAL COSTS – VENTILATION

- › Preferable to locate fans underground, to avoid noise.
- › If a shaft is required, the cost will depend on the cross-sectional area, conditions, location and length.
- › A 20-ft- diameter unlined shaft constructed using raise boring techniques may cost \$4,000–\$7,500/ft. Conventionally sunk shafts will be higher cost.
- › Ventilating stone mines is quite different to coal or many hard-rock mines. Large openings typically require high-volume, low-pressure fans. Depending on the capacity required, a fan installation could range from \$500,000–\$2,000,000.

CAPITAL COSTS – EQUIPMENT

The underground opening size, working grades, and production rate will drive the equipment selection and fleet requirement

- › Large openings may allow familiar surface equipment to be used (e.g., 988/990 loaders and 775 trucks).
- › Smaller openings or steeper grades may require specific underground LHD loaders and ADT-type trucks.
- › Selecting electric or diesel equipment will impact cost. Electrical equipment (especially for drill jumbos, roof bolters and explosives truck) can reduce ventilation challenges.
- › For production ranging from 0.5–1.5 MTPA, equipment capex could range from \$8–10 million (low end) to \$15–20 million (high end).
- › Crusher and conveyor (if required) would be additional.

OPERATING COST – DRILL & BLAST

Headings require horizontal drilling using drill jumbos

- › Hole spacing much closer than surface mining at about 5ft spacing.
- › Increased number of holes increase blasting cost due to number of delays and boosters.
- › ANFO is blown into holes using custom powder truck.
- › For a heading with 25 ft mining height and room width of 45 ft, approximately 1,300 tons per 15 ft advance, explosive costs may range from \$0.40-0.50 per ton.
- › For a bench shot with 50 ft mining height and room width of 45 ft, approximately 2,600 tons per 15 ft advance, explosive costs of about \$0.20-0.25 per ton.

Also, blast design may be affected by proximity to urban infrastructure

OPERATING COST – SCALING

Newly blasted/mucked areas require scaling to reduce loose material on back and ribs before bolting

- › **Scaling equipment is specific to underground mining and needs to match mining height.**
- › **Dedicated crew required for scaling.**

OPERATING COST – GROUND CONTROL

The mining height has significant impact on ground control cost. Good roof conditions can allow minimal bolting

- › Bolt length, spacing and anchorage depends on rock mechanics investigation.
- › For 25 ft mining height and room width of 45 ft, approximately 1,300 tons per 15 ft advance.
- › Bolting cost of about \$0.15-0.25 per ton dependent on bolt spacing, length and anchorage.
- › If subsequent benching, there is minimal ground control cost for the tons obtained from benching (ribs may require some attention).
- › Unless there is experience in adjacent mines in same formation, generally plan conservatively and adjust with experience.



QUESTIONS / DISCUSSION

THANK YOU



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