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Montana Tech's Underground Mine Education Center

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INTRODUCTION

In 2010, Montana Tech was gifted 65 acres of land immediately west of the campus. The parcel of land included an old silver mine called the Orphan Boy Mine. The Orphan Boy and its sister, Orphan Girl, were developed about1895 and operated until 1956. In addition to the gift of land, a significant industry gift was obtained to develop a first class training facility, which we call the Underground Mine Education Center (UMEC). The UMEC has been funded primarily by industry through donations of dollars, equipment, and supplies.

The UMEC is a unique hands-on, educational environment for today's students who are being trained to find, develop and process the worlds' natural resources. The center complements courses in mining engineering, geological engineering, environmental engineering, metallurgical engineering and occupational safety and health. It also serves as a as research facility utilized by students and faculty, and other organizations interested in doing research a hard rock underground mine.

LOCATION

The Orphan Boy and Orphan Girl Mine are located approximately 700 feet (ft.) apart and the Orphan Girl Mine is part of the World Museum of Mining. Underground they are connected on various levels and all levels below the 100 ft. level are currently flooded. The Orphan Boy mine was 804 ft. deep and Orphan Girl was 3200 ft. deep. The surface locations of the two mines and some of the underground workings on the 100 ft. level are shown on Figure 1 (2015).

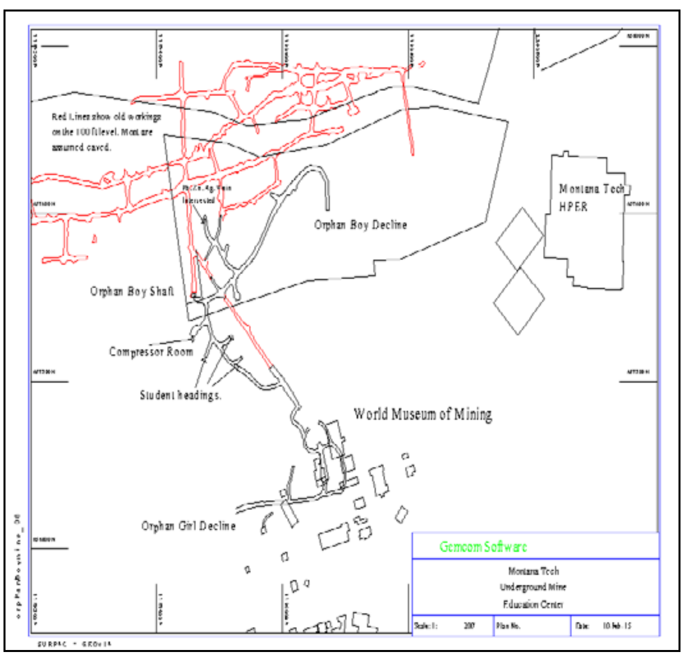

Figure 1. Location of the UMEC.

CONSTRUCTION

Land ownership was gifted from BP/ARCO in 2010 and planning started immediately. In June of 2011, site development for the decline to the 100 ft. Level of the Orphan Boy began with a satisfactory portal site developed (Figure 2). We hoped to be able to start driving the decline in July.

Figure 2. Starting the decline.

However, the portal was sited approximately 125 ft. away from a natural gas line that bisected the Montana Tech campus. While outside the right of way for the line, Northwestern Energy requested that no blasting be performed near the gas line until such time as the gas line was abandoned in the fall so decline development was put on hold. The gas line was officially abandoned in January of 2012.

While work at the Orphan Boy was curtailed, Tech worked with the World Museum of Mining to drive over 400 feet of new workings on the 100 ft. level of the Orphan Girl Mine to eventually connect the two mines on the 100 ft. level.

Finally, in April of 2012, work started on the new Orphan Boy decline (Figures 3 and 4). A 10 ft.by10 ft. decline was driven at a 15% slope. All surveying for the decline was done by the senior author.

By November, the decline had been driven over 700 ft. and had intersected the Orphan Boy shaft (Figures 6 and 7). The 100 ft. shaft station was stabilized and an emergency escape way established. The Orphan Boy shaft was caved at approximately the 50 ft. level. Theisen Team Contractors were hired to stabilize the shaft with 40 feet of cellular concrete with the remainder filled with concrete and gravel.

Ventilation was established by installing a 50hp reversible fan at the ventilation decline of the Orphan Boy Shaft. An electrical room was constructed adjacent to the shaft. Phones and data lines were installed. WIFI has been installed. A compressor room was constructed and a 600 cfm electric compressor installed. A small tool and storage room was completed.

Figure 3. First blast.

Figure 4. Constructing the Portal.

Figure 5. Portal Cover.

Next, work commenced on driving a drift to connect with the Orphan Girl. Over 500 ft. of drift was driven providing much needed room for class activities, research and an additional escape way. Additional work continues to this day to expand the underground working and provide space for the practical underground mining class, surveying, etc., and to provide space for research projects.

Figure 6. Looking down the Orphan Boy shaft from the surface.

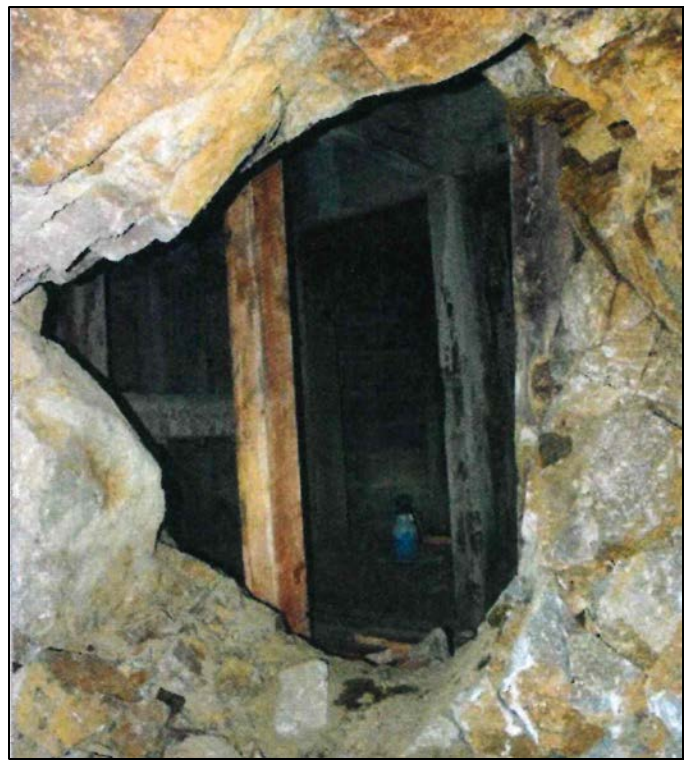

Figure 7. Breaking into the 100ft. shaft station.

In August of 2018, a 50 ft. by 120 ft. mine building was erected next to the portal. When finished, this building will be used for equipment storage, repairs, and contain a dry, classroom and office space. Figure 8 shows an artist's conception of the completed building, which is presently just a shell.

Figure 9 shows the layout of the UMEC as of October, 2018. All the workings shown in blue have been driven either by the contractor for the project or by students in the practical mining class. The workings in yellow are old workings of the Anaconda Company and are mostly caved.

Research

Research being done in the UMEC grows each year. The Orphan Boy mine shaft was an important objective of the construction of the UMEC. In 2010, the Montana Bureau of Mines and Geology received a US DOE grant to investigate the feasibility of using the warm water of the Orphan Boy as a heat source to heat the newly constructed Natural

Resources Building. To utilize the water, the Orphan Boy shaft had to be intersected at the 100 ft. station.

Figure 8. Artists concept of the Mine building.

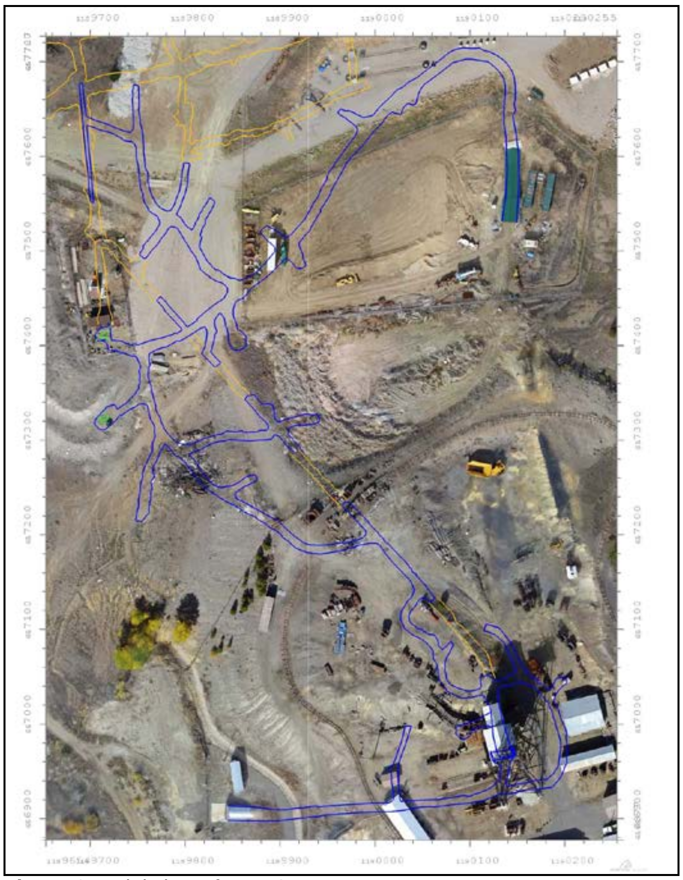

Figure 9. Arial view of UMEC.

The underground workings of the Orphan Boy Mine are estimated to contain over 300 million gallons of warm water (76°F). The 2010 grant was to evaluate the feasibility of using heat exchangers to capture the heat of the warm water at the Orphan Boy mine and heat pumps to heat Montana Tech's new Natural Resources Building. Based on the feasibility study, in 2012 the DOE awarded Montana Tech a grant to install down-hole heat exchangers in the shaft and heat pumps in the Natural Resources Building (a 55,000 ft^2 building).

As designed the system uses "off-the-shelf' parts", making the basic configuration straightforward with the exception of the Down-hole Heat Exchangers (DHEs), which need to be placed into the vertical shaft. Because there are few or no examples of placing heat exchangers in a vertical shaft, a study was made by Thornton, Wahl and Blackketter (SME reprint 2013) to model the heat exchanger placement and configuration in the vertical shaft such that thermal currents develop between the stope and vertical shaft, via the horizontal cross drifts, in order to thermally move the water and thereby provide the required energy.

The down-hole heat exchanger consisted of 14,000 ft. of poly pipe placed in two compartments of the shaft. Two manifolds were constructed with each receiving 10 pipes for inlet and 10 for outlet. Each manifold contained 7000 ft. of pipe. The manifold were weighted so that they wouldn't float when placed in the shaft. Water in a closed system is pumped to the Natural Resources building where it supplies heat to the heat pumps and then is returned to the shaft. Figures 10 through 14 show one of the heat exchangers being installed.

Figure 10. Poly lines being lowered down ventilation shaft.

Other Research Projects

The CDC-NIOSH Office of Mine Safety and Health Research has used the UMEC for several research projects. The first was a research project focused on demonstrating the effectiveness of the emerging fiber-optic-based distributed strain and temperature (DST) and distributed acoustic sensing (DAS) technologies under various mining conditions and facilitating their adoption by the mining industry and thereby contributing to mine safety. The primary objectives of the research project were to demonstrate that the DST technology can be employed in an underground mine, attached to rock surfaces and in boreholes, to reliably and accurately detect ground deformation of different characters, and that it is able to monitor fluctuating temperature profiles and detect localized temperature anomalies when deployed along rock surfaces, in boreholes, and submerged in flooded shafts.

Multiple strands of strain-sensing cable were installed near the Orphan Boy shaft, along the surfaces of the drifts in different orientations and with different attachments (grout and epoxy), and in grouted boreholes crossing diagonally through a pillar.

Figure 11. Completed manifold.

Figure 12. Looking down ventilation shaft.

These studies demonstrated that the field performance of the system under a variety of underground conditions and allow investigation and solution of issues associated with borehole and rock-face attachment of the cables. Data was compared to that collected using traditional geotechnical instrumentation and to predictions made using numerical models. A key test was to determine how the strain sensing cable correlated with data detected with traditional geophones. In the spring of 2015, a Geophysical Engineering Senior Design Team designed, installed, and tested the traditional geophone array. The geophysicists installed geophones in 6 inch diameter holes drilled in the walls of the mine.

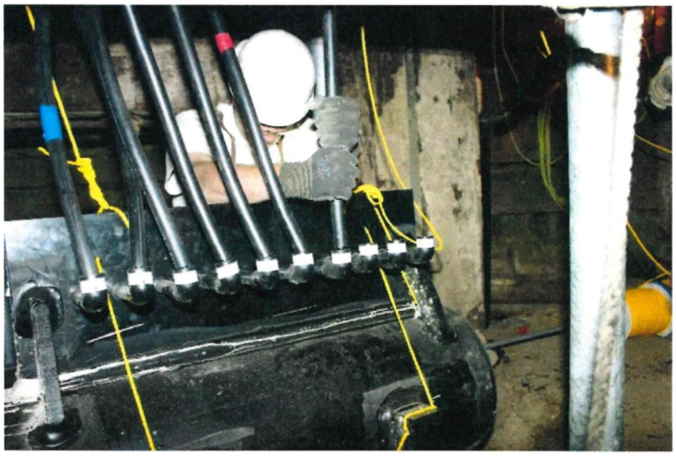

Figure 13. Welding poly pipe to manifold.

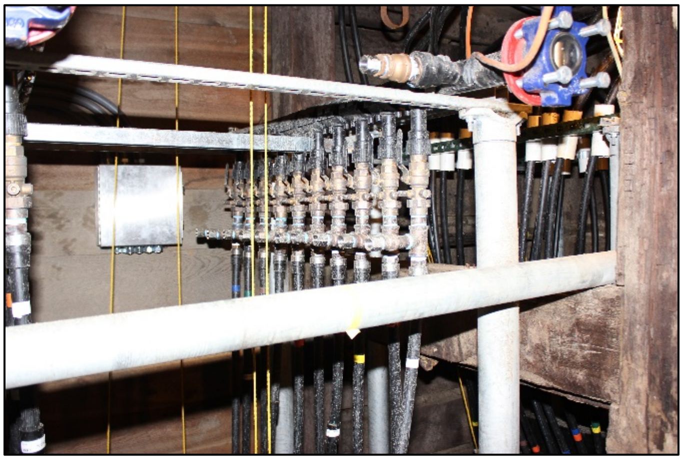

Figure 14. System in place in shaft.

Figure 15. Students installing strain sensing cable in Orphan Boy Shaft.

Figure 16. Drilling 6 inch hole in pillar.

Figure 17. Geophone installed in 6 inch hole.

Corrosion Coupon Research-A NIOSH funded project. NIOSH installed corrosion coupons throughout the mine. They corrosion observed is compared to other mines.

Instrumented Rock Bolt Installation and Blast Protection Cap testing-A NIOSH funded project that began in began June 2017 and completed in 2018.

Transformed Infrared Transmission (FTIR) Method vs. X-Ray Diffraction for Respirable Crystalline Silica Analysis in Three Montana Mines (MS Thesis), Siobhan Wock, SHIH- Professors Hart and Rosenthal provided faculty support. 2017

Performance of Fiber Optic Sensing Technologies for Distributed Monitoring of Ground Deformation and Temperature in an Underground Facility (MS Thesis), Calvin Kammerer- Professors MacLaughlin and Rosenthal provided faculty support. 2017

Comparing Fiber Optic Sensing to 3-Component Geophones (MS THESIS) Nikolas Nesladek, Geophysical Engineering. Professor Speece supervised. 2017

Characterization of Granite and subsequent Ground Control Management Plan at Orphan Boy Mine - **(MS thesis),** Emily Rose. Professor Rosenthal advisor. 2017

Historic Structure Response to Underground Blasting, Logan Connolly. Professor Rosenthal is project advisor. Expected completion 2018

Jackleg Drill Noise Analysis and Oil Mist Sampling, Senior Design project by Travis Oakason & Ryan Stemple, SHIH students- Professors Hart and Rosenthal supervised. 2017

Distributed fiber-optic temperature sensor validations using field deployments in the flooded Orphan Boy mine shaft.in Butte, MT,(MS Thesis) Elliott Mazur- Professors MacLaughlin supervised. 2017

Determining tolerant species of trees that will grow in Butte's degraded soils - Professor Conrad is growing trees in an underground greenhouse.

Investigation of rock drill vibration and effectiveness of anti-vibration gloves-Chase

Billington, Professors Hart and Rosenthal Julie Hart.

VOD -A **Shottrack** VOD instrument has been acquired and will be used to monitor the velocity of detonation with the purpose of optimizing the blasts.

STUDENT USE

What a Blast Camp

The UMEC is the centerpiece of the "What a Blast Camp" that the Mining Engineering program offers to high school students. The students visit the Yellowstone Talc Mine, the Stillwater Mine, Gem Mountain, the Underground Mine Education Center and use an equipment simulator furnished by Cloud Peak, Inc. At the UMEC they learned to use a jackleg drill, how to run a LHD, and participate in blasting the round they drilled out. The blast is always the highlight of the camp.

Figure 18. "What a Blast Camp" at Yellowstone Mine.

Practical Mine Class (Min 140)

The practical mining class is held in both the fall and spring semesters. The students enjoy the opportunity to learn practical mining techniques, using a jackleg drill, an LHD, and how to install rock bolts. Most importantly they learn safety in the underground environment. The students have driven over 1000 ft. of drift. For several students the experience has led them to obtaining great summer internship positions and permanent positions after graduation.

Other Classes

Every spring our underground surveying class is held in the mine. The rock mechanics class and ventilation classes use the UMEC for several practical exercises in the mine. Montana Tech's Occupation and Safety program perform a number of lab assignments involving dust measurements and noise measurements.

Figure 19. A 6ft.6in student using an LHD.

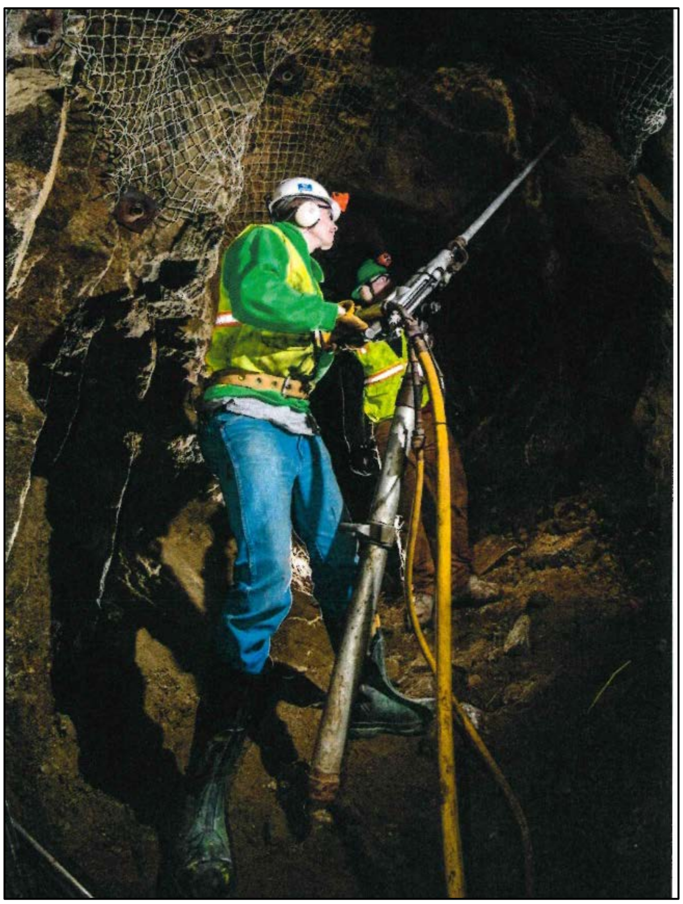

Figure 20. Student using a jackleg drill.

Other Uses

Montana Tech annually sends multiple teams to the International Mining Competition. Montana Tech hosted the completion in 2016 and constructed a competition site at the UMEC because of the availability of water and compressed air. Students can practice at the site in warm weather or practice underground in winter.

Figure 21. Gift from Stillwater and Joy.

Figure 22. A Loaner jumbo from Fletcher.

Use by other Universities

The mine is the only underground mine in Butte where the geology and mineralogy of the vein systems that Butte is famous for can still be observed and sampled. As such, the mine has had a number of geology students from BCIT, McGill, Washington State University, the University of Montreal and West Virginia University come to visit the mine. In addition, BCIT has leased the facility twice to teach their students practical mining, mine mapping, and mine geology.

Figure 23. A setting that is hard to beat.

Thanks

We wish to thank our many corporate and individual contributors to this project.

REFERENCES

Thornton, Rory, Wahl, Neil and, Blackketter, Don (2013), "CONVECTION MECHANISMS FOR GEOTHERMAL HEAT XCHANGERS IN A VERTICAL MINE SHAFT", SME PREPRINT.