propriate correction factor to get a more accurate airflow rate for the calibration. One of the advantages of using AMS sensor data to obtain airflow rates over the manual spot check is that the AMS method can produce a time-averaged airflow rate, while the spot check only produces the airflow at the moment of measurement.

Conclusions

A new method was developed to calibrate a mine ventilation network model using the continuously monitored AMS air velocity. The method was demonstrated using the mine ventilation network model of the SRCM and monitored AMS data. Results from the study indicate that the instantaneous air velocity data cannot be used directly for the ventilation network calibration because of fluctuations. It is found that temperature and air velocity readings are well correlated. The sensor location correction factors were obtained to be used to convert the measured point readings to the average velocity over the cross section of the airway. Results from this study demonstrate that the continuously monitored AMS air velocity data can help mine ventilation engineers better calibrate their ventilation network models to achieve more accurate ventilation simulation results. ■

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. Mention of any company or product does not constitute endorsement by NIOSH.

References

A list of all references is available in the full paper.

Stress redistribution in a longwall yield pillar – A comparison between active seismic tomography and theory

Erik C. Westman[1,*], Jessica M. Wempen[2], Dallan J. Coons[2], Michael K. McCarter[2] and William G. Pariseau[2]
[1]Department of Mining and Minerals Engineering, Virginia Tech, Blacksburg, VA, USA
[2]Department of Mining Engineering, University of Utah, Salt Lake City, UT, USA
*Corresponding author email: ewestman@vt.edu

Full-text paper:
Mining, Metallurgy & Exploration (2022) 39:1017–1026, https://doi.org/10.1007/s42461-022-00579-z

Keywords: Longwall mining, Seismic tomography, Coal, Ground control

Special Extended Abstract

Safe, efficient underground mining is dependent upon proper pillar sizing. Pillar sizing is typically based on a combination of observation of prior behavior, point measurements, theory and numerical modeling. The actual stress redistribution within a pillar, while assumed for many years, has rarely been imaged. Such imaging can help confirm whether or not theoretical and numerical modeling methods agree with actual conditions within a pillar.

This research presents a case study from a longwall mine in the western United States. A two-entry, gate-road yield pillar in the headgate of the mine was instrumented with seismometers and convergence monitoring stations, and was monitored over a period of about six months as the longwall face approached the pillar. In this paper, the stress distribution imaged using seismic tomography is compared to the stress distribution expected from theoretical models, geotechnical measurements and numerical models. The tomography results generally agree with those proposed by theory, convergence measurements and numerical modeling results. The agreement of the methods provides validation for the theorized stress redistribution, and this study provides further evidence that tomography can indicate the redistribution of induced stress within a mined rockmass and is another tool available to ensure that mining is conducted safely and efficiently.

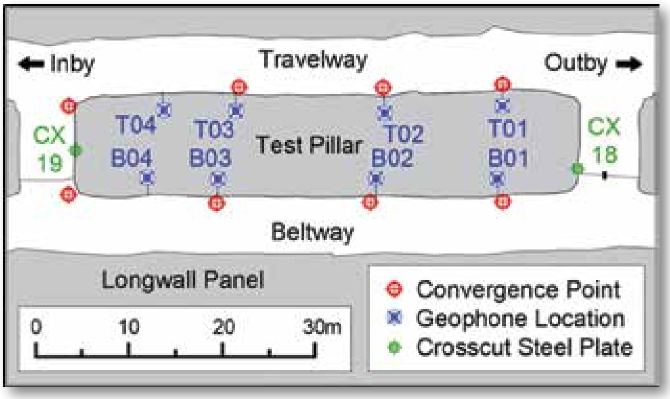

Fig. 1 Locations of geophones and convergence stations.

Background

Review of coal pillar design indicated potential shapes for the stress distribution within pillars by showing that the stress distribution assumed in the Mark-Bieniawski pillar design formula is a pyramid for square pillars and a rectangular, elongated pyramid (with a linear apex) for rectangular pillars [1]. The load is a maximum in the center of a pillar (at a point for a square pillar and along a line for a rectangular pillar) and a minimum at pillar ribs. The ultimate strength

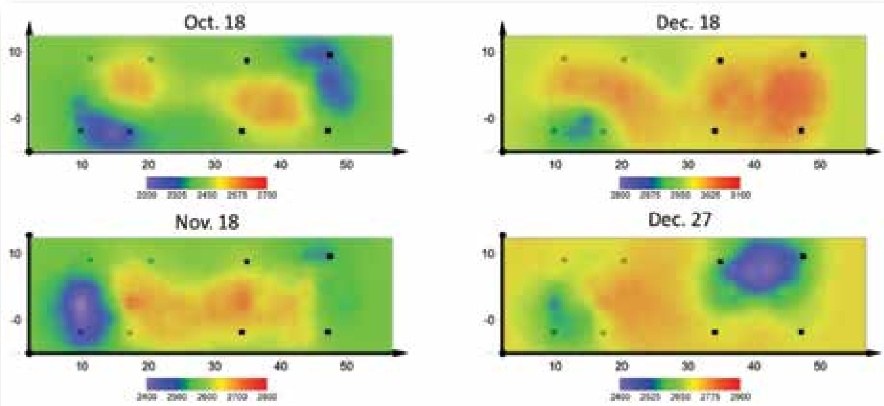

Fig. 2 P-wave velocity tomograms for four time periods, geophones shown as black markers. Axis units are meters; velocity units are meter per second (m/s).

of the pillar is governed by the strength of the core. Prior to this demonstration, Wagner [2,3] presented a model of stress redistribution within a pillar that has been broadly accepted: failure occurs starting at the perimeter of a pillar and gradually progresses inwards toward a confined core which will fail if the stress exceeds the ultimate strength of the pillar.

Methods

Figure 1 shows geophone locations and the locations where convergence was monitored. Six uniaxial and two triaxial geophones were installed in the study pillar. Drillhole collar locations were selected to provide unobstructed access to the rib and to maintain approximately equal spacing between the sensors on the travelway and beltway sides of the pillar.

Active seismic sources were generated by striking the pillar with a battering ram. During the study, the longwall face advanced approximately 940 m toward the pillar. Active source data from four dates — Oct. 18, Nov. 18, Dec. 18 and Dec. 27, 2017 — were selected for seismic analysis as part of this study. For each active source event, travel times through the pillar were calculated by differencing the arrival times at each geophone from the arrival times at the geophone nearest the source events.

The velocity distribution within the pillar was calculated for each of the four dates using seismic tomography to evaluate how the stress redistribution within the pillar estimated by tomography compared to theoretical and numerical results.

The mean velocity of all P-waves traversing the pillar on a specific date is an indicator of the overall, general stress within the pillar at that time. Laboratory studies have shown that there is a somewhat monotonic relationship between stress and P-wave velocity [4,5]. In many of the studies the P-wave velocity increases with increasing stress, until the stress within the sample nears its ultimate strength, at which time microfractures develop within the sample resulting in a reduced P-wave velocity.

Results

For this study, the mean velocity within the pillar increased from 2,532 m/s on Oct. 18 to 2,618 m/s on Nov. 18 and 2,899 m/s on Dec. 18, and then dropped to 2,404 m/s on Dec. 27. This relative increase in velocity is similar to prior work in laboratory coal specimens [6], and as would be expected, these results are parallel to those shown in Fig. 2. The broad conclusion that can be drawn solely from the overall mean velocity is that the pillar appears to have reached its ultimate load sometime between Nov. 18 and Dec. 27; the peak velocity occurs sometime between those two dates. Of the four study periods, Dec. 18 has the highest recorded mean velocity, but it cannot be stated definitively that the peak velocity occurred precisely on this date.

Overall, the convergence monitoring data appear supportive of the tomographic results. In the tomography study, the mean velocity increased across the entire pillar for the first three dates, indicating increasing load, and then decreased from the third to fourth date, indicating post-peak behavior. This observation is compatible with the observed convergence measurements; the greatest amount of convergence occurred between the third and fourth dates.

Summary and conclusions

The results obtained in the current study agree to a large extent with the expected distribution and relative magnitude of induced stress, as presented in prior studies. P-wave travel time tomography provides a method to examine the redistribution of stress throughout a specified volume of a rockmass, complementing other methods such as point-location measurements and numerical modeling. The information provided by the tomograms can be useful to confirm that an optimal pillar design is being used — a design that maintains safety and does not sacrifice productivity.

Active seismic tomography was conducted on a yield pillar in a longwall mine in the western United States. Although computed tomography has been relied upon in the medical field for decades, and has the ability to provide information about conditions throughout a rockmass, it is still not a common method in the mining industry. This study provides an opportunity to compare results from active seismic tomography in a well-defined, unambiguous study to those from current theory, numerical modeling and point measurements.

The tomography results generally agree with those proposed by theory, convergence measurements and numerical models. This observation provides two conclusions: (1) the agreement of the methods provides validation for the theorized stress redistribution, and (2) this study provides further evidence that tomography can indicate the redistribution of induced stress within a mined rockmass and tomography is another tool available to ensure that mining is conducted safely and efficiently. We can also conclude that at the mine in the study, for the loading conditions, the pillar size was within acceptable bounds, the pillar did not fail prematurely; at the same time, it was not over-designed and thus inefficient. ■

Selected references

1. Mark C (2000) State-of-the-art in coal pillar design. Trans-Soc Min Metal Explor 308:123–128
2. Wagner H (1974) Determination of complete load deformation characteristics of

coal pillars. In: 3rd Congress International Society Rock Mechanics. US National Academy of Science, Denver, CO, 1076–1081
3. Wagner H (1980) Pillar design in coal mines. J of South Afr Inst Min Metall 801(1):37–45
4. Terry NB (1959) Dependence of elastic behavior of coal on microcrack structure. Fuel 3:125–146
5. Seya K, Suzuki I, Fujiwara H (1979) The change in ultrasonic wave velocities in triaxially stressed brittle rock. J Phys Earth 27:409–421
6. Shea-Albin VR, Hanson DR, Gerlick RE (1991) Elastic wave velocity and attenuation as used to define phases of loading and failure in coal. No 9355. Bureau of Mines, US Department of the Interior, 43 pp

A novel approach for the separation and recovery of titanium, scandium and iron from acidic wastewater, and utilization of red gypsum

Jinrong Ju[1,2,3], Yali Feng[1,*], Haoran Li[2,3,*] and Ben Wang[1]
[1]Civil and Resource Engineering School, University of Science and Technology Beijing, Beijing, China
[2]Key Laboratory of Biochemical Engineering, Institute of Process Engineering, Chinese Academy of Sciences, Beijing, China
[3]University of Chinese Academy of Sciences, Beijing, China
*Corresponding author emails: ylfeng126@126.com, hrli@ipe.ac.cn

Full-text paper:
Mining, Metallurgy & Exploration (2022) 39:1297–1312, https://doi.org/10.1007/s42461-022-00600-5

Keywords: Acidic wastewater, Red gypsum, Phosphoric acid precipitation, Solvent extraction, Ammonium jarosite

Special Extended Abstract

Acidic wastewater is at present directly neutralized with lime or limestone, which wastes resources such as titanium, scandium and iron and generates a great deal of solid waste. This study proposes a novel approach for the separation and recovery of titanium, scandium and iron from acidic wastewater, and utilization of red gypsum. The proposed process not only recovers valuable metals from acidic wastewater but also treats the red gypsum that has previously been dumped.

Background

The sulfuric acid leaching method is an essential process for producing titanium dioxide from ilmenite due to the low requirements for feed grade [1]. In China, more than 90 percent of titanium dioxide is yielded by the sulfuric acid leaching method, and the production of 1 ton of titanium dioxide engenders about 8 tons of acidic wastewater [2,3]. At present, acidic wastewater is usually disposed of by neutralization with lime or limestone [4], which not only produces red gypsum as an industrial byproduct but also wastes resources. In this work, in order to effectively separate and recover titanium, scandium and iron in acidic wastewater and realize the resource utilization of red gypsum, a precipitation-solvent extraction-leaching process is proposed.

Experiment procedure

Figure 1 presents the process flow diagram of a novel approach for the separation and recovery of titanium, scandium and iron from acidic wastewater along with the utilization of red gypsum, which mainly comprises four experimental processes: (1) separation of titanium from acidic wastewater to obtain titanium phosphate, (2) extraction of scandium from the filtrate to obtain scandium trioxide, (3) leaching of red gypsum with raffinate to obtain calcium sulfate and (4) separation of iron from leaching filtrate to obtain ammonium jarosite, and obtaining ammonium sulfate from the filtrate after iron recovery by evaporation.

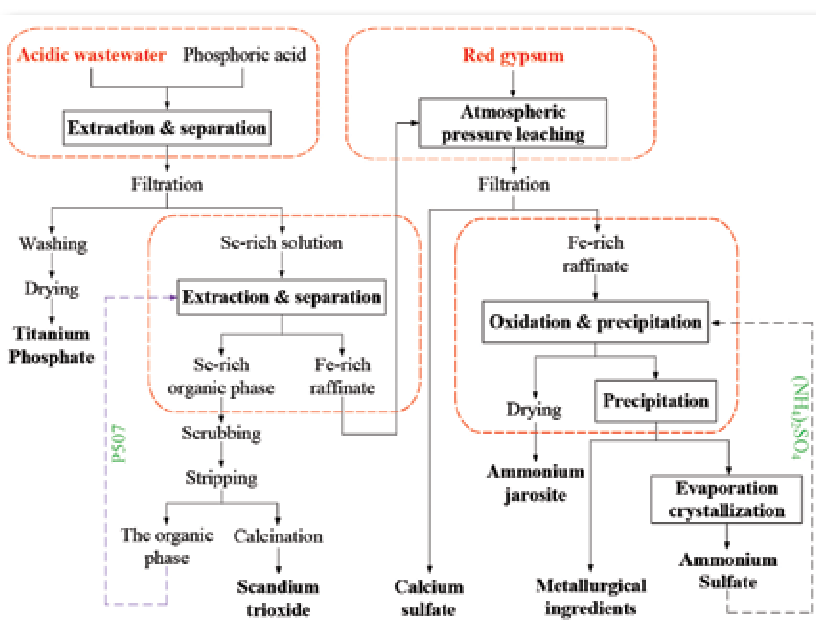

Fig. 1 Process flow diagram for the extraction of titanium, scandium and iron from acidic wastewater, and utilization of red gypsum.

Results and discussion

Titanium phosphate has caught the attention of many researchers due to its excellent physical and chemical stability, low solubility and strong adsorption, which is generally synthesized in a strong acid medium. Although most phosphates, such as $Fe_3(PO_4)_2$, $FePO_4{\cdot}2H_2O$, $Mg_3(PO_4)_3$, $AlPO_4$ and