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Distributed acoustic sensing/distributed strain sensing technology and its applications for block cave progress monitoring, rock mass preconditioning, and imaging

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Abstract

The block cave mining method has grown over the last decade due to its technical and economic benefits. One of the challenges that remains is monitoring the rock mass response, cave progress, and surface subsidence throughout the operation.

Distributed fibre optic sensing (DFOS) is an advanced technology, however, the mining sector remains underserved by this technology that enables an integrated, real-time and high-resolution platform to monitor microseismicity, fracture network propagation, and strain/deformation all using one run of fibre sensing cable.

Distributed acoustic sensing (DAS) interrogators acquire seismic signals along many kilometres of fibre, equivalent to a string of geophones lain end-to-end every metre over its length. DAS enables both active and passive seismic applications and advanced analysis techniques using the same cable and setup. In addition, the DAS system captures low-frequency strain data in real-time indicating fracture network orientation, propagation, and slow strain changes within the rock mass in response to block cave operation.

Because of its wide aperture, DAS systems reduce hypocentre uncertainty compared to conventional geophone arrays. Sampling that is both wider and denser allows for additional precision for seismic imaging techniques such as tomography, ambient noise tomography (ANT), or multichannel analysis of surface waves (MASW). For example, these methods can be used to analyse subsurface velocity variations associated with rock type and structure, or to measure near-surface velocity changes associated with subsidence.

The distributed strain sensing (DSS) interrogator can be integrated into the DAS/fibre system to provide real-time or periodic absolute strain measurement and track rock mass deformation over long periods of time.

This paper provides an overview of DAS/DSS technology in applications such as block caving, preconditioning, and vertical seismic profiling (VSP) seismic surveys. It reviews acquisition design, analysis, and demonstrates the technology's capabilities and limitations in detecting and processing seismic and strain data.

Keywords: *distributed fibre optic sensing, distributed acoustic sensing, distributed temperature sensing, distributed strain sensing, multichannel analysis of surface waves, vertical seismic profiles*

1 Introduction

Chasing resources deeper into the earth comes with additional operational hazards that need to be mitigated. In situ stresses increase with depth and can vary widely between different structural regions and geological rock types. Higher ambient stresses directly lead to microseismicity growing exponentially with depth in both size and frequency. In addition, stress changes associated with an increased mined rock volume also contribute to longer seismic decay times after a large-magnitude event (Vallejos & McKinnon 2009). Strain redistribution caused by excavation, or ground deformation caused from mining-related seismicity can lead to highly energetic rock bursts and ejections. Reliable real-time measurements of stress, strain, and temperature in mines can provide valuable data to mitigate risk and prevent catastrophic events that could lead to damaged equipment, infrastructure, personal injury, and in the worst case, a loss of life (Miah & Potter 2017).

To reduce risk and environmental impact, mines will continue to rely on remote sensing equipment to quantify subsurface activity. Current technology such as extensometers and geophones provide reliable sampling but can be expensive and cumbersome to install.

DFOS sensing, specifically distributed acoustic sensing (DAS) and distributed strain sensing (DSS), provide unique advantages over extensometers and geophones to increase the density, sensitivity, reliability, and safety of mine networks. For example, measuring along the full length of the fibre is essential when a point of interest is not exactly known (e.g. strain loading in a tunnel). In these scenarios, point sensors can miss details that are captured by distributed sensing as shown in Figure 1.

DFOS arrays can be employed to monitor hydraulic preconditioning of the rock mass, monitor the cave propagation with time (including the yielded zone, the seismogenic zone, and the elastic zone), monitor surface subsidence, and infrastructure health including tunnels and shafts. For visualisation purposes a DFOS acquisition system is shown in Figure 2 outlining the interrogator, light pulse, and backscattered light to be measured. A further introduction to DFOS and the technology is provided in the following section.

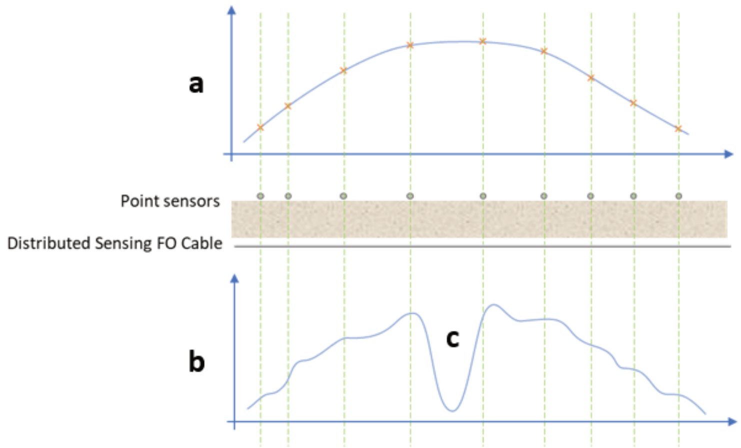


Figure 1 Point sensors versus distributed sensing. Point sensing (a) has less spatial resolution than distributed sensing (b). Distributed sensing can capture measurements that otherwise would not have been resolved (c)

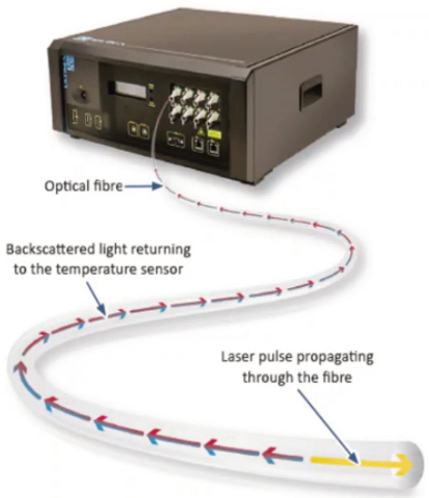


Figure 2 Fibre interrogator measuring a backscatter response

2 Distributed fibre optics sensing technology

DFOS has been used extensively in alternative energy (Binder & Abatchev 2021), environmental and earth sciences (Hudson et al. 2021), infrastructure (Monsberger & Lienhart 2021), carbon capture and utilisation (Hopkins et al. 2021), oil and gas (Jin & Roy 2017), and mining (Riedel et al. 2018; Bellefleur et al. 2018). Unfortunately, substantial mining projects do not present as frequently compared with other industries. The inherently gradual developments of mines mean DFOS solutions have been slow to be adopted for mining applications.

The application of fibre optic infrastructure to transmit data over long distances is well understood, yet not all light that is transmitted via an optical fibre is received at the opposite end. During transmission, some of the light is attenuated via absorption and scattering along its length (Figure 3). Distributed sensing relies on one or more of the three types of interaction between the laser pulse and the glass in the optical fibre. Rayleigh scattering has the same frequency as the laser pulse so the glass acts like a weak mirror (it is the same scattering that makes the sky blue). The two other types of interaction, Brillouin and Raman scattering, are much weaker, and are generated by an interaction between the laser pulse and natural vibrations in the glass. Brillouin has a small frequency shift from the incident light, and Raman a much larger frequency shift, see Figure 3. The interrogator is designed to capture a specific scattering interaction and is so used to measure external environmental parametres such as temperature, acoustics, or strain.

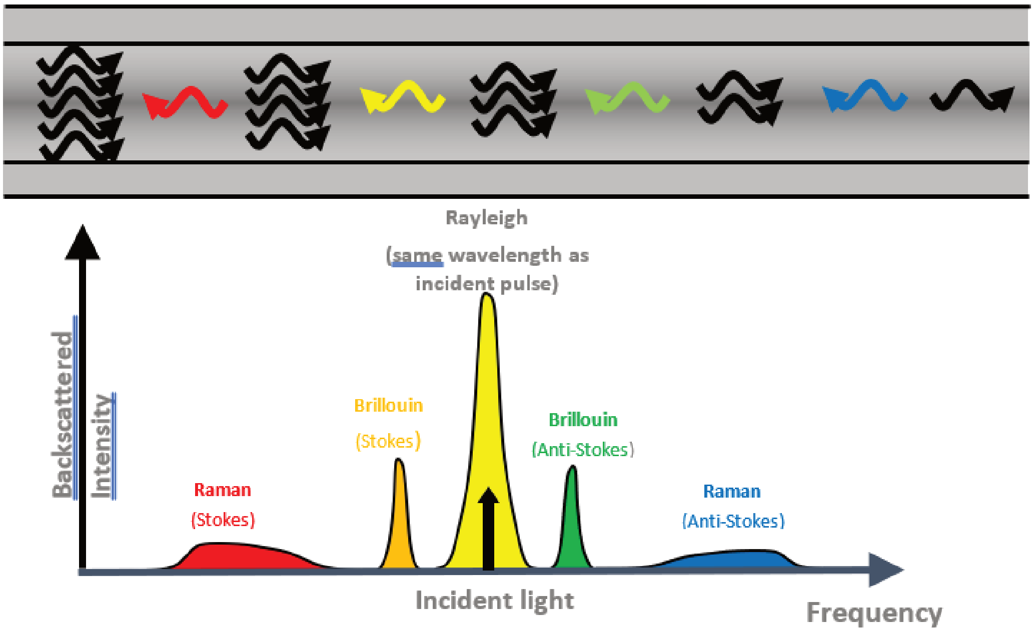


Figure 3 Wavelength/frequency of light scattering phenomenon recorded by interrogators. The different light scattering processes are Rayleigh, Brillouin, and Raman. Elastic scattering of light (Rayleigh) maintains wavelength while inelastic scattering of light (Raman and Brillouin) change wavelength based on the amount of energy absorbed or released (i.e. Stokes shift)

Fibre interrogators are built to analyse backscattered light occurring from different scattering phenomena. Brillouin and Raman backscattering can be used to measure strain and temperature to 1 micro-strain and 0.01°C levels of resolution respectively. Rayleigh backscattering can be used to measure both acoustics and dynamic strain with a high level of accuracy (Parker et al. 2014; Miah & Potter 2017).

The result of using backscattered light as signal has the effect of turning many kilometres of fibre into a dense array of sensors, with a channel output density as high as every 0.10 m. For reference, a 10 km long fibre optical cable interrogated via an DAS system writing data every meter is analogous to having 10,000 one-component geophones lain end-to-end. Acoustic amplitude, phase, and frequency are all captured making DAS a full solution for seismic applications.

One of the challenges in using DAS for seismic applications is the fibre's sensitivity to the incoming wavefield (advantages and disadvantages are discussed in more detail in the following section). Weak arrivals may not significantly strain the fibre to be detected above the system's noise floor. For the best performance, the enhanced interrogator needs to monitor along an engineered optical fibre. The differences between the various optical fibres used in distributed sensing are outlined in Figure 4. Engineered fibre enhances the signal response 20 dB over standard fibre to provide 120 dB of total dynamic range. A 20 dB lowering of the noise floor is beneficial for the DAS applications discussed in the subsequent sections.

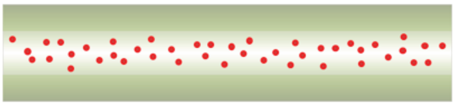
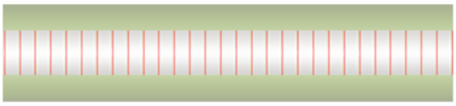
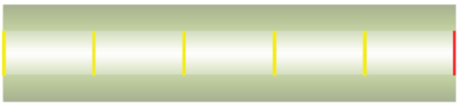
Standard fibre • worst for signal, best for loss • uncontrolled phase relationship causes SNR variation (fading), which is an issue in some interrogator architectures	
Highly doped fibre • higher signal • doping significantly increases losses	
Continuous enhanced fibre • much higher signal, reasonable losses • still uncontrolled phase relationship from multiple scatterers meaning there is a limit to how the extra light can be effectively used	
Engineered fibre • much higher signal, reasonable losses • distinct scattering locations give control of the optical signal amplitude and phase • with the right interrogator, the extra light can be used to reduce the noise floor to the theoretical (shot noise) limit	

Figure 4 Description of differences between optical fibres

3 Rock mass monitoring using DAS

Using DAS for rock mass monitoring is transforming how we monitor (3.1) and explore (3.2) in mines. DAS is a full waveform sensor, meaning it is sensitive to amplitude, frequency, and phase (Figure 5). This means that for many applications, DAS solutions are suitable to supplement or replace geophone-based systems. There are, however, trade-offs to using a DAS system, and in this section, we will discuss in detail some of the capabilities and challenges of using DAS systems.

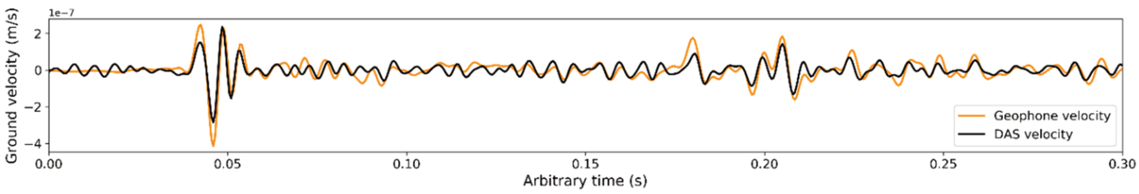


Figure 5 Comparison of geophone recorded microseismic arrival to DAS recorded arrival. Both signals match closely in amplitude, polarity, and frequency

The most important capability of a DAS system is its ability to be a distributed sensor. As previously mentioned, a 10 km fibre, if data was output at every metre, would be equivalent to 10,000 single-component geophones lain end-to-end over its length. A sample microseismic event arrival over a long borehole is shown in Figure 6. The advantages of dense sampling cannot be overstated. Geophone-based location methods typically depend on the accurate picking of primary and secondary wave arrivals, then using a time residual approach to find the location that best minimises the cumulative time between the theoretical and picked arrivals for all sensors. The major shortfall of this approach is that time residuals, and therefore location errors are high when working in a poorly defined velocity space. This is less of a concern when working in predictable, well sequenced stratigraphy with little structure. An example would be many onshore oil field operations where the rock mass is often relatively homogenous with minimal velocity contrast. Conversely, mining velocity models are typically heterogenous with changing rock types/velocities and with abundant structure. The dense sampling native to DAS increases hypocentre location accuracy by modelling more ray paths and minimising the effects of velocity ambiguity. Moreover, further spatial sampling of the propagating wavefield is expected to add additional accuracy to moment tensor inversions. In some DAS recordings, the focal sphere transition is readily seen in the seismic recordings (Figure 7). Finally, tomographic imaging of the subsurface benefits from additional ray paths to increase the accuracy of subsurface models. This is discussed in more detail in Section 3.2.

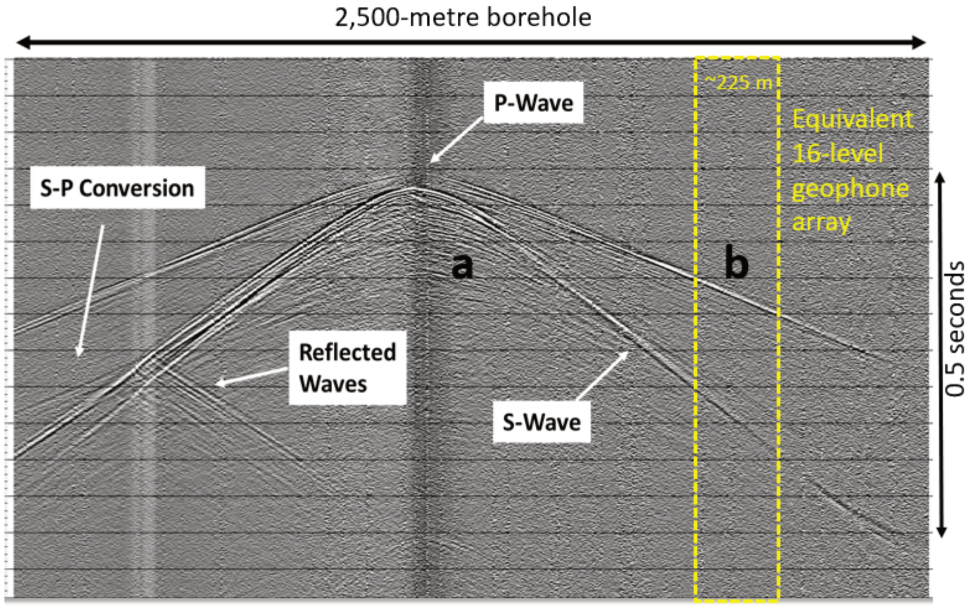


Figure 6 **Sample microseismic event recorded on a Carina array. The microseismic event (a) has a lot of detail, including P-waves, S-waves, reflected waves, and S–P conversions. A comparable 16-level geophones array (b) would capture much less signal fidelity**

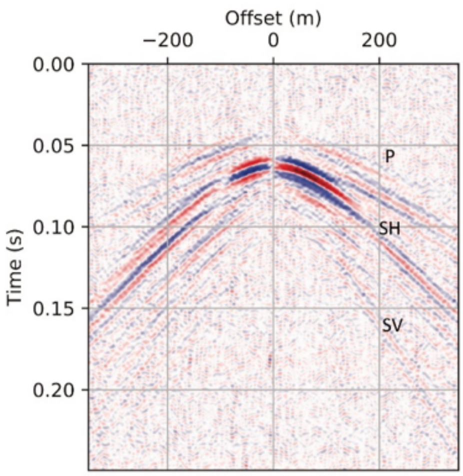


Figure 7 **Example DAS recording of an event with clear P, SH, and SV arrivals, with polarity reversals observed in the SH and P (Baird et al. 2020)**

The second key benefit of DAS, and all DFOS systems generally, is their small footprint and minimal form factor. Including fibre protective jackets and reinforcement, cable diameters are often 5–10 mm, and can weigh 30–100 kg/km. The benefits of having such a small formfactor are that DAS arrays can be installed easily, quickly, and cost effectively along tunnel walls, or in boreholes (fluid, cased, or open). Additionally, because fibres can be spliced to form a 'turn-around' connection at the cable ends, multiple boreholes can be daisy chained together and be monitored with a single interrogator (Figure 8). Crucially, because these systems have no moving parts (cooling fan excluded), they can record for years with simple over-the-air updates and do not require onsite maintenance or site visits. For these reasons DAS monitoring is expected to increase mine safety, reduce the mine carbon footprint, and drive cost reductions.

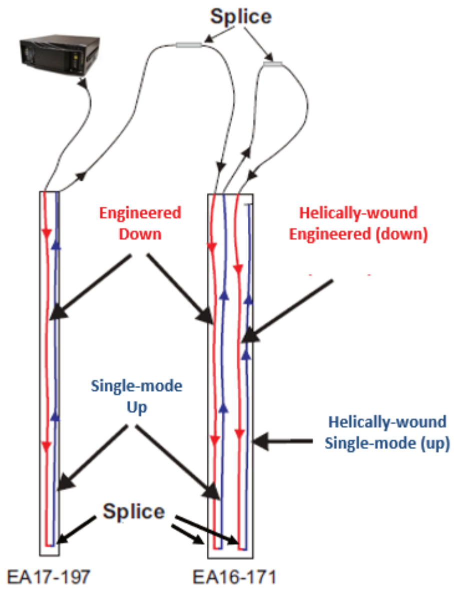


Figure 8 Sample daisy chain configuration from a mine VSP program where they tested several cable configurations (engineered fibre, standard single-mode, and helically-wound). Cables are daisy chained between boreholes with splices identified at surface. Turn-around splices also exist at the base of each borehole. The EA16-171 borehole had fibre looped twice through its length (edited from Bellefleur et al. 2018)

For all the benefits of DAS there are some inherent limitations and challenges that need to be addressed. First and foremost, DAS is most sensitive to strain along the axis of the fibre, and least sensitive to strain orthogonal to the fibre (Figure 9). While theory states that primary waves arriving orthogonal to a DAS array should be invisible (i.e. ϴ = 90° in Figure 9b), and real-world data confirms this, for arrivals even a few degrees off 90°, signal is resolvable. Additionally, for incidence angles of minimum P-wave sensitivity, S-waves signal have maximum sensitivity (Figure 9c), so waveforms are rarely poorly sampled. For most applications the single-component nature of DAS does not greatly affect results, however, for some simple well designs without borehole deviation, more than one fibre array may be necessary to uniquely determine hypocentre location.

Event magnitude calculations are also non-trivial when comparing geophones and accelerometers to DAS. Geophones are simple systems that measure movement of a central weighted mass within a solenoid. Converting this signal from velocity space to displacement space to capture and fit a magnitude response is a simple process. DAS, however, records strain rates and not velocity. The result is that more consideration needs to be given when converting a DAS response to displacement. The details of those considerations are outside of the scope of this paper but recent work like that completed by Lellouch et al. (2020) shows a strong correlation between magnitudes calculated via DAS when compared with geophones (Figure 10).

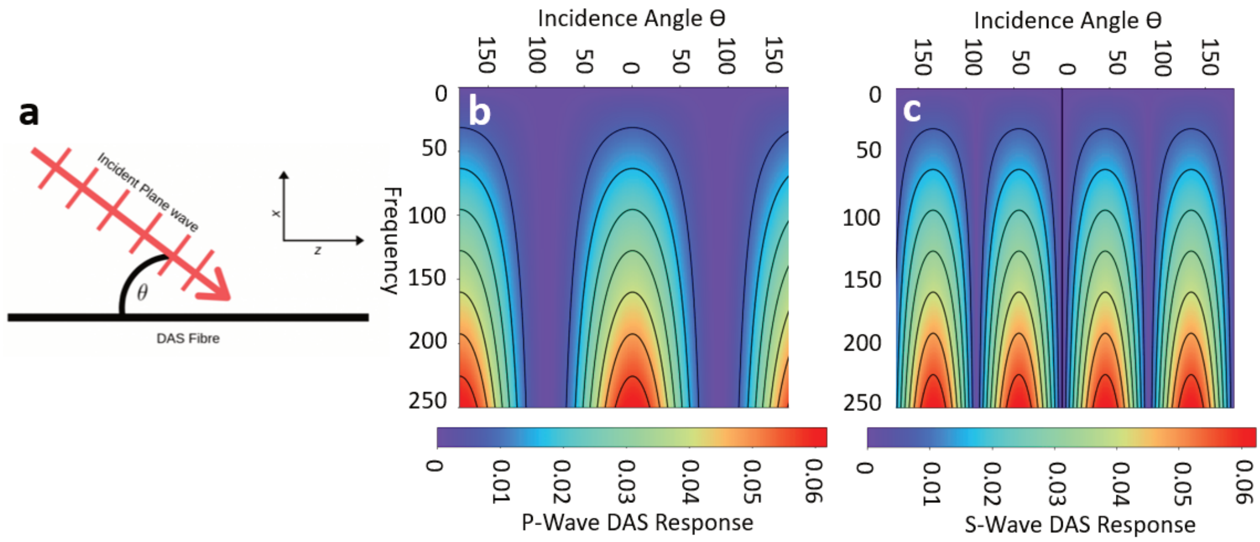


Figure 9 Amplitude response spectrum for a DAS system to a plane wave arrival as a function of frequency and incidence angle. A sample diagram of a planar wave arrival is show in (a), with the incidence angle frequency response shown for P-waves (b) and S-waves (c) (modified from Chambers 2022)

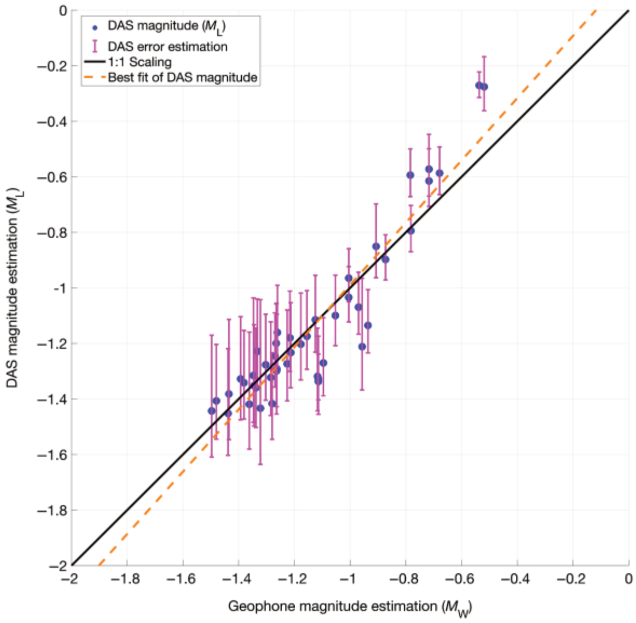


Figure 10 DAS local magnitude estimation for detected events on both downhole DAS and surface microseismic array as part of the geothermal FORGE project. The black line shows a 1:1 scaling between the catalogues, and the dashed line indicates the regression fit between the magnitudes, the slope is 1.12 (from Lellouch et al. 2020)

Data management and processing are the final challenges DAS is overcoming. Data management for acoustic sensing systems requires forethought. These issues are amplified, however, when considering the many thousands of channels typical of a DAS array. Additional acquisition planning must be undertaken to acquire only the necessary channels and at adequate channel spacing and frequency to maintain healthy data volumes. Figure 11 shows the amount of data storage necessary for raw signal given different array lengths at typical microseismic recording frequencies. Generally, there are few upper limits on sampling frequency over short distances, however, as the laser interrogates greater lengths there are sampling limitations imposed by the repetition rate of the laser as showing in Figure 12.

Finally, additional signal fidelity in the form of frequency, spatial density, and total recording aperture can cause processing times to lag geophone recordings that provide a lower volume of input data. Most recently, these issues have been solved though implementing circular buffers, optimising triggering to limit false positives, improving algorithms so processing can run effectively in real-time without needing substantial investment in computer hardware or through data decimation that acts to reduce the advantages of recording DAS initially.

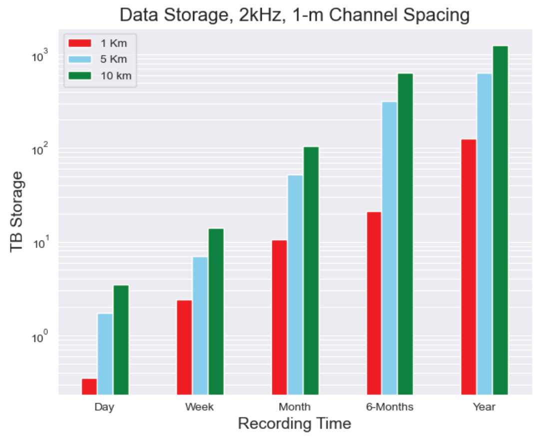


Figure 11 Data storage requirements for DAS data acquired at 2,000 Hz with 1 m channel spacing

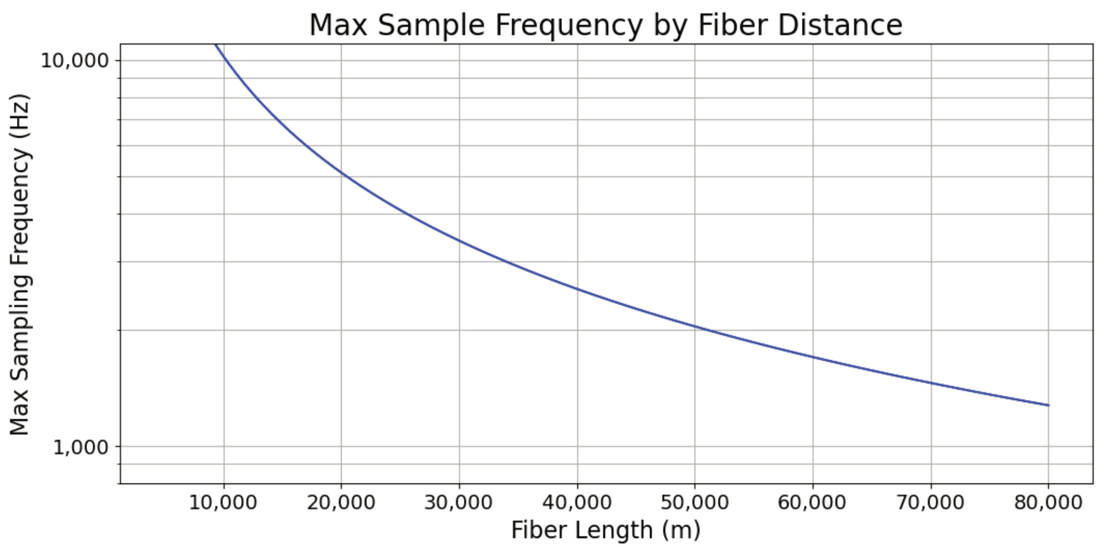


Figure 12 Maximum sampling rate available given interrogation distance. Sampling compromises are only experienced at large distances, where light loss effects would likely make recording not possible

3.1 Microseismicity using DAS technology

DAS microseismic monitoring for block caving operations is accomplished in several different ways. For block caving operations that undergo hydraulic fracturing to precondition the rock mass, the first, and likely easiest monitoring solution would be to utilise the existing borehole infrastructure drilled for preconditioning. This is true for large surface-based programs as shown in Figure 13, and for subsurface programs. A subsection of microseismic events is shown in Figure 14 for a subsurface preconditioning program. Preconditioning programs are becoming more common as they are projected to reduce the risk of large-magnitude events and mitigate the rockburst hazard in mines (Lett 2022). Equipping existing boreholes with fibre would allow the hydraulic preconditioning program to be mapped similar to how microseismicity is mapped for oilfield fracturing operations (Figure 13a). Fracture dimensions determined from microseismic will help evaluate the total stimulated rock volume and the general efficacy of the program. Next, after these wells are instrumented and production has started, these boreholes can be further utilised to map ongoing microseismic associated with the breakdown of the orebody in the seismogenic zone (Figure 13c). Zones not stimulated by the initial injection program, and not exhibiting a seismic response prior to yielding could suggest areas of higher seismic hazard. The preconditioning boreholes, over time will be sheared away as the rock cleaves and yields, the propagation of the cave back can further be monitored through fibre severing over time.

The second method of monitoring microseismic is through purpose drilled monitoring boreholes outside of the targeted body (Figure 13b). Boreholes could be drilled from within the mine subsurface infrastructure or from the surface. These boreholes will remain intact during mine operation and can provide many years' worth of data for microseismic mapping, and, depending on the length of the borehole, a higher level of location accuracy compared to a traditional geophone.

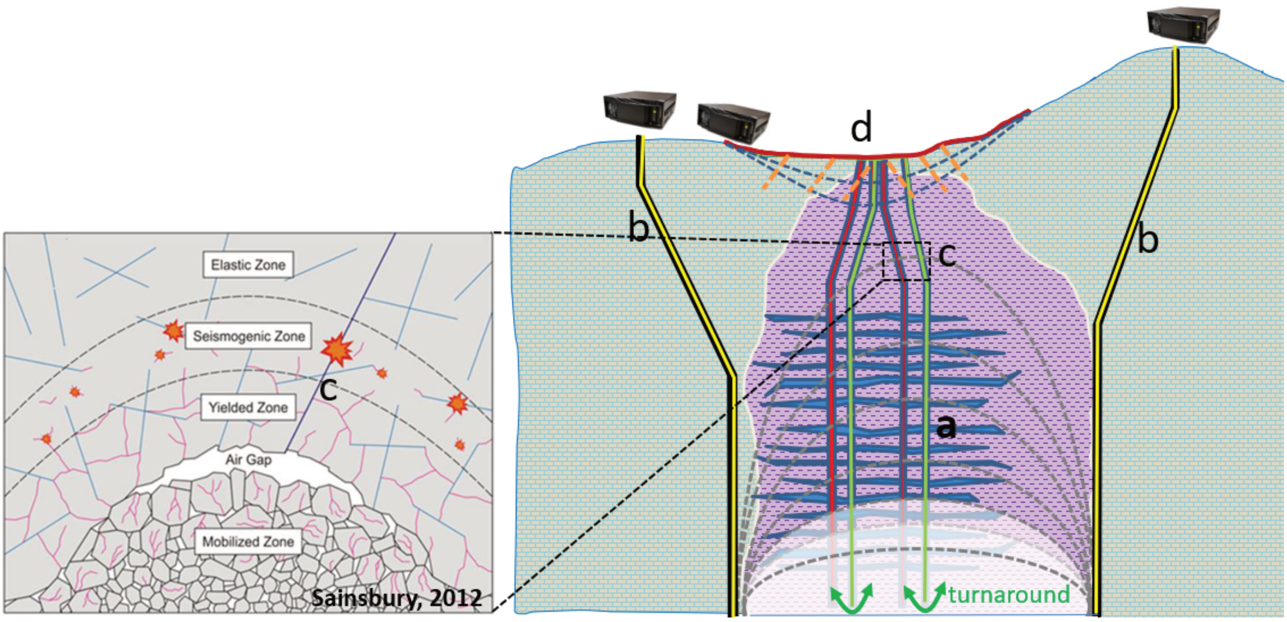


Figure 13 Possible methods of monitoring block caving operation with DAS (left image modified from Sainsbury 2012)

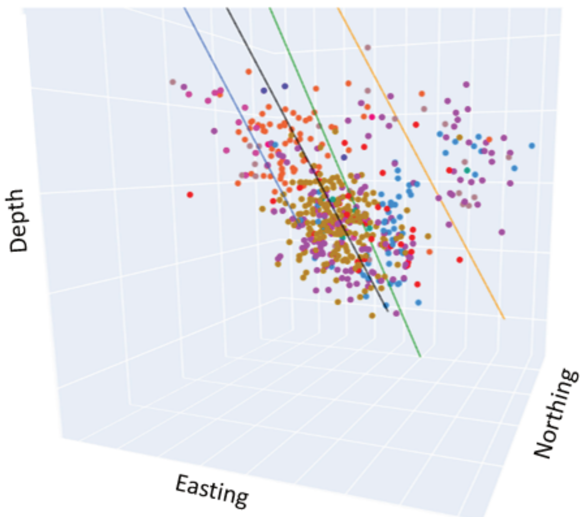


Figure 14 A rock mass preconditioning program run from short boreholes drilled within the mine. A small subset of the total recorded events is shown

The third, and potentially the most novel approach to monitoring is to instrument mine tunnels and shafts (Figure 15). Retrofitting fibre to existing subsurface infrastructure, or deploying fibre behind shotcrete for new infrastructure, would, in effect, turn your entire tunnelling network into a seismic array. In addition to providing a seismic network, this fibre could be utilised for strain and shape monitoring (Monsberger & Lienhart 2021), temperature monitoring, and telecommunication. Such a fibre system would provide much more value and safety than just acoustic monitoring.

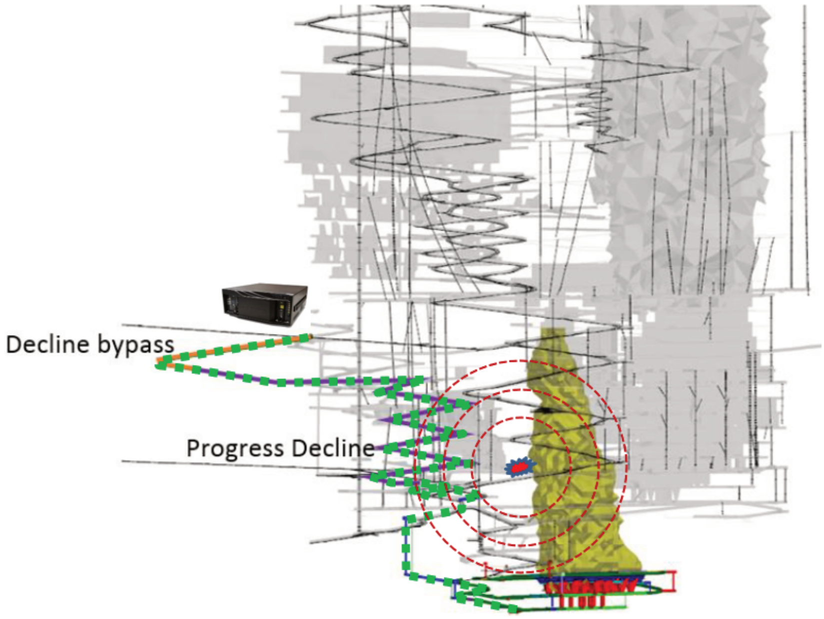


Figure 15 Leinster cave mine bypass installed after switching from a sublevel caving operation to block caving. The green dashed line shows where fibre could be installed and monitor for both infrastructure health and be used as a seismic array to achieve greater location accuracy (image modified from Hopkins 2018)

The fourth method of microseismic monitoring is instrument the near-surface with fibre (Figure 13d). Surface seismic instrumentation tend to be noisier and have poorer depth resolution than subsurface equipment. DAS surface deployments however can give additional depth resolution for seismicity as they capture more wavefield moveout, and therefore make resolving depth less ambiguous. Surface DAS arrays would also be sensitive to near-surface microseismic associated with structural changes that result from subsidence. This would be a novel application and hopefully allow for a greater understanding of subsidence, and what areas are showing indicators prior to the exposure of surface relief.

3.2 Seismic imaging

Presently, 3D tomography is being used in many mines to help track the propagation of the cave and the excavated areas. Figure 16 shows high quality tomography results produced by Törnman & Martinsson (2020), as the tomography results are produced as part of their mapping process. Tomography helps image a subsection of our mine, or our full mine provided we have adequate ray paths. To confidently run tomography inversions, you need either many distributed sources of known location or many distributed sensors. More often than not for mines, passive microseismic records are used as inputs for inversion, however, active sources can be used as well when available.

Traditionally, geophone datasets provide sparse coverage of mine geometry and therefore, many sources are needed to provide adequate tomography results. DAS arrays enable additional resolution for tomography through using more ray paths than would have otherwise been available with standard geophone systems (refer to Figure 6). With additional ray paths, fewer events are needed to run inversion and could make tomography results available to mines traditionally less seismically active. Additionally, for mines experiencing elevated seismicity, DAS provides higher resolution and may resolve more nuanced velocity and density changes than had previously been identified.

To further utilise DAS for exploration, exploratory boreholes provide a convenient opportunity when instrumented with fibre to further image the mine's surrounding geology though seismic profiling. Promising results are shown in the work by Riedel et al. (2018) for the Kylylahti mine in eastern Finland (Figure 17). The results show that there is little difference between geophones (Figure 17b) and DAS (Figure 17c) signal quality for the purposes of mine imaging, but DAS arrays are advantageous due to their comparatively low cost and ease of deployment. As Riedel et al. (2018) states "DAS VSP surveys provide a very promising tool for mineral exploration and mine planning. We believe that the application of in-mine VSP surveys could generally be used to plan ongoing exploration drilling more strategically and thus potentially reduce the number of required boreholes" (p. 538).

Connecting DAS with geophysical imaging techniques for exploration advances us towards the goal of substituting expensive drilling with cheaper imaging applications to reduce waste. There are an additional two aspects worth noting in this research. The first is that the Riedel data were acquired using standard fibre and not engineered fibre for additional signal fidelity and noise reduction. If engineered fibre were used, we would expect to detect more reflectors and achieve an overall higher resolution. Secondly, reflector 11, which is outside of the geologically modelled area and furthest to the west in Figure 17b, c shows higher resolution on the DAS array when compared with the geophone array. The additional resolution is the contribution of the wider aperture of the DAS array which allows greater detections at further offsets.

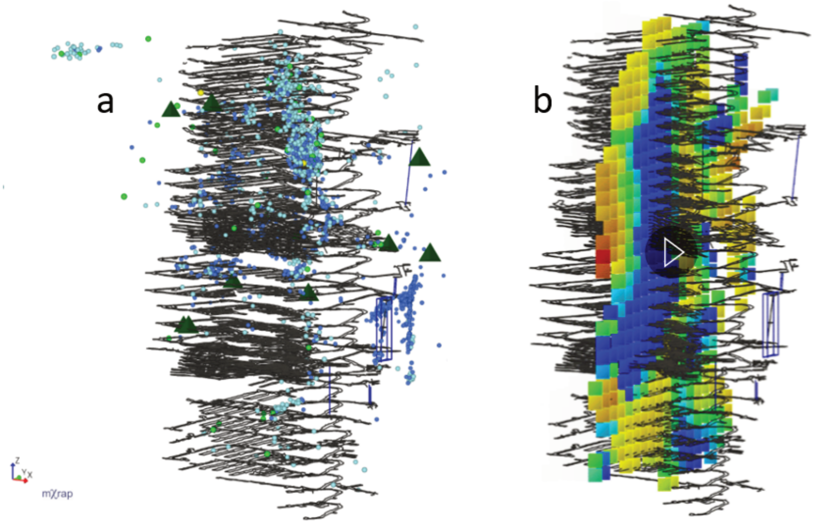


Figure 16 Tomography generated from Garpenberg mine as part of a microseismic event processing. The geophones positions (as triangles) and microseismic events are outlined in (a). The inversion produced P-wave solutions is shown in (b). The blue low velocities zone are areas where the orebody has been extracted (Martinsson 2022)

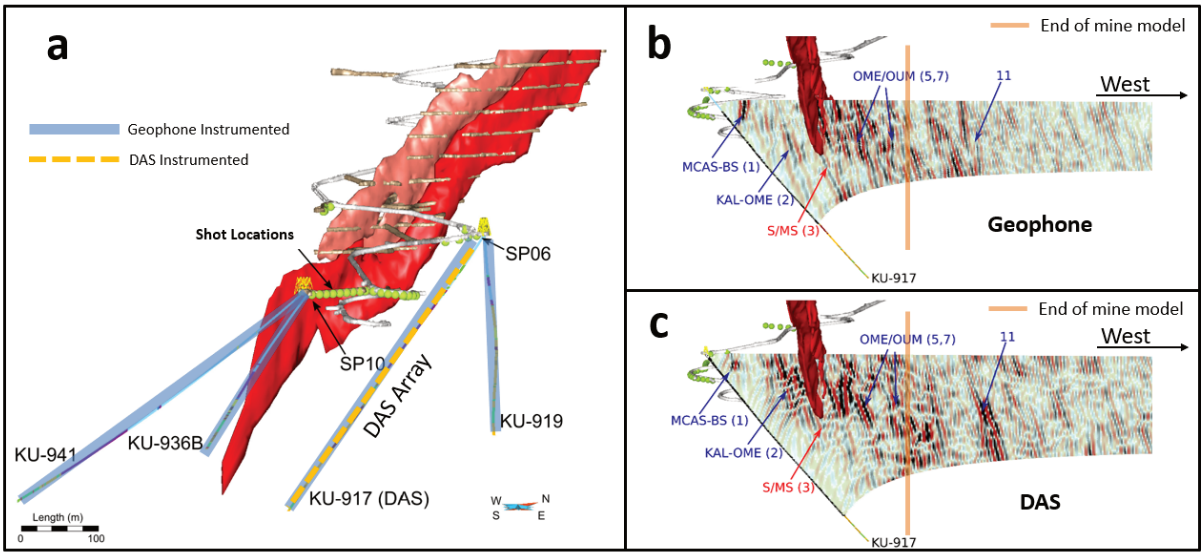


Figure 17 Results of vertical seismic profiling completed in an Kylylahti polymetallic mine in eastern Finland. The geological model of the Kylylahti sulfide deposit (red/pink) and instrumented exploration boreholes in blue and dashed yellow lines (a), the seismic sources are indicated by the green dots in the tunnels. The geophone (b) and DAS (c) results are compared with section through the mine east to west. The results are comparable between DAS and geophone, however all data west of the 'end of mine model' line (solid orange) is unknown due to a lack of geological information in that area (edited from Riedel et al. 2018)

4 Strain monitoring using DSS

Strain measurements can be acquired in one of two ways with single-mode fibres. The first approach utilises Rayleigh (elastic) scattering. This is the same method used for measuring microseismic in DAS applications discussed in the previous DAS section. A unique feature of DAS arrays is they can measure very low-frequency responses along the fibre. Unlike a geophone that is unable to accurately resolve frequencies below 10–15 Hz, DAS arrays remain unaliased at low frequencies. For this reason, Rayleigh backscattering is effective in measuring strain at the sub mHz bandwidth. These strain measurements are useful in DAS applications as the same interrogator used for microseismic measurements is also capable of measuring strain simultaneously. Figure 18b shows a sample strain response recorded on a DAS array between an injecting borehole and a monitoring fibre.

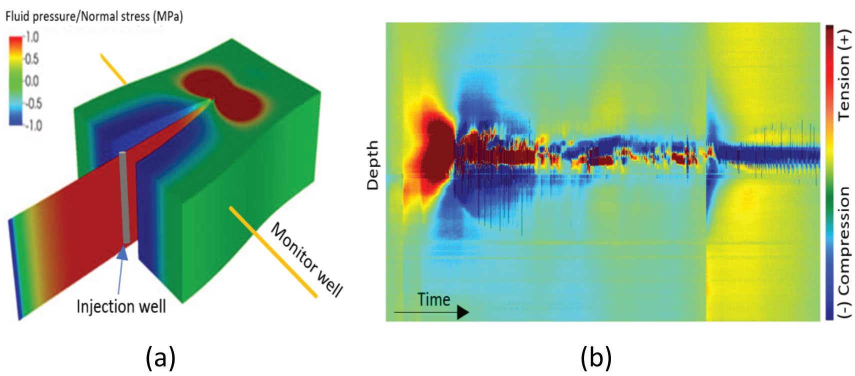


Figure 18 Strain response as recorded on a DAS array for an injection-monitoring borehole pair. A schematic is shown in (a) and the strain response over time is shown in (b) (Wu et al. 2020)

The second way strain in measured is through inelastic scattering. Inelastic scattering includes Raman and Brillouin (Figure 3) and occurs when the propagating light pulse either loses energy to the medium or gains energy from the medium as part of the scattering process. Brillouin has a small frequency shift from the incident light, and Raman has a much larger frequency shift. The frequency offset of the Brillouin light from the source light, known as the Brillouin shift, depends upon the strain in the optical fibre. So, by measuring this Brillouin shift all along the fibre, we can measure the strain all along the fibre. By tightly coupling the fibre to an object of interest e.g. a tunnel, shaft, or borehole, the strain the object is under is also measured.

The Brillouin shift also depends upon the fibre temperature so, when accurate measurements are needed in an uncertain environment, it is necessary to have an independent temperature measurement from a distributed temperature sensing (DTS) system. A temperature uncertainty of 1°C translates to a strain uncertainty of 20 µε, when temperature correction is needed, the quality of the DTS used can provide the actual strain resolution limit. The best in class DTSs have a resolution of 0.01°C, and this makes an important contribution here.

If the fibre is not significantly strained, then the Brillouin data can alternatively be used for temperature measurements. Usually, a DTS is the better choice, but the DSS is optimum for ranges above 35 km, or where there are large optical losses, for example when measuring remotely in subsea installations.

DSS is performed with interrogators developed specifically to measure strain and utilise the Brillouin response. The cons of using a DSS system are that the fibre must be well coupled (typically this means grouting for boreholes). The pros are that a DSS system can uniquely measure the absolute strain acting on a system and does so with a relatively low data volume. Recently, field tests of DSS systems have been shown to resolve strain of ±7.5 µε (Zhang et al. 2021). Best in class DSS interrogators show resolution of ±2 µε, and a spatial resolution of 50 cm (Figure 19). Furthermore, because measurements do not need to be continuous to quantify strain, DSS interrogators can operate on multiple fibres simultaneously. Multi-fibre interrogation is achieved through an optical switch, which allows one interrogator to cycle through multiple fibres in sequence to record for a predetermined time interval.

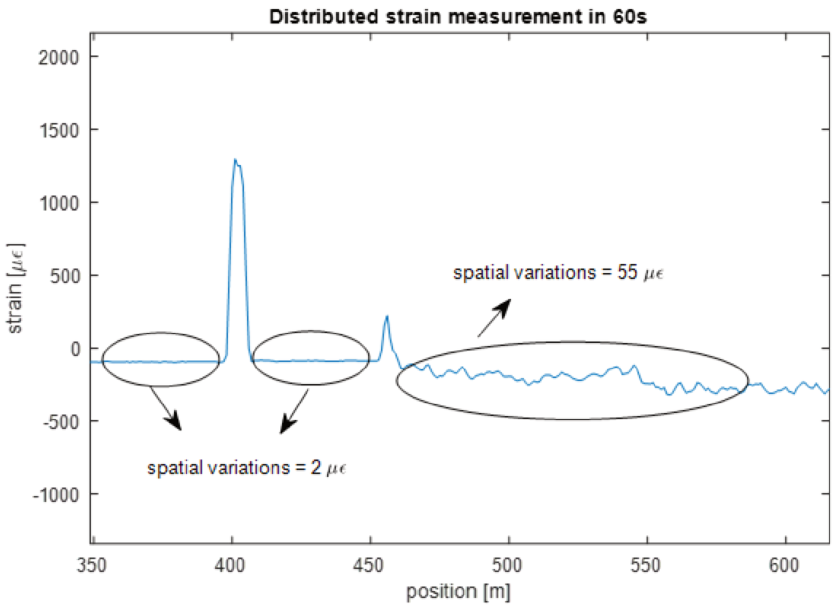


Figure 19 Distributed strain measurements as captured from a Silixa DSS interrogator. Here a resolution of 2 µε is achieved over a spatial resolution of 3 m. This fine resolution allows the system to faithfully capture the 55 µε strain distribution in the sensing fibre

For cave mining operations, DSS sensing allows discrete monitoring of multiple fibres on a reoccurring loop. For instrumented boreholes in the mass of an orebody actively mined (Figure 13a, c), strain profiles generated over time allow continuous tracking of how the orebody is experiencing stress and strain during its development. Furthermore, as the rock mass breaks away and severs the fibre cable, the DSS system can track the propagation of the cave overtime (Figure 13d).

For infrastructure monitoring, DSS systems can monitor tunnels and shaft networks equipped with fibre. Strain monitoring identifies areas experiencing stress redistributions and loading as a function of aged infrastructure, mine development, and/or seismicity. A distributed and temporal strain map of the subsurface infrastructure helps identify weakened areas susceptible to strain bursting hazard.

5 Edge Platform

The concurrent broad and dense nature of fibre monitoring, combined with the various types of data that can be collected, can lead to ballooning data volumes without foresight and best practices in place. Temperature and strain data generally output manageable data volumes. Microseismic data rates however can balloon if not properly managed as seen in Figure 11. The Edge Platform tackles this problem by frontloading initial data processing and conditioning at the point of collection rather than requiring costly wireless transfers or physical shipping of hard discs.

The Edge Platform consists of the server connected to the interrogator(s), the data RAID (redundant array of inexpensive discs) and computer peripherals at the point of collection, but more importantly the cloud-hosted data management service. The Edge Platform allows for over-the-air updates, continuous data quality control and health checks, conditional processing, and live changes in recording parameters. For example, if a VSP acquisition was planned for a mine, and continuous strain data was being recorded in a series of tunnels and/or boreholes, acquisition type could be remotely switched to record full bandwidth for the program duration. Similarly, if blasting operations were planned for a subsection of the mine, data collection could be initiated for regions where the fibre is available via an optical switch.

Cloud-based management of remote hardware and acquisition parameters is a user driven solution that ensures only valuable information is stored, and results are available immediately following the acquisition.

6 Conclusion

DFOS is transforming how modern mines acquire and make use of their data. By deploying fibre into exploration boreholes and along mine shafts and tunnels, we can convert an entire mine into a distributed acoustic and strain sensing array. DAS microseismic would provide additional accuracy for event locations and therefore give more confidence in seismic hazard maps. Continuous and distributed strain monitoring could act as an early warning for tunnels and shafts that are experiencing stress–strain loading because of mine development and propagating seismic waves. This would be accomplished with minimal equipment and allow mines to acquire data for years without needing costly sight visits and equipment maintenance. These combined benefits of DAS can make future mines safer, reduce their carbon footprints, and drive efficiencies in data collection.

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