The seismic monitoring system in the Velenje mine, Slovenia

Paper-Nr.: 2931

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The Velenje lignite mine is located in Slovenia with depth of mining level around 40 m to 150 m below sea level. Lignite deposits are characterized by a high amount of enclosed methane gas which can be released suddenly during the mining progress. This causes great danger for the miners through explosions, rock falls, bursting of walls or particle ejection.

Since October 2016 a reengineered, extended seismic monitoring system has been established in Velenje mine with newly developed receivers. So the sensors are allowed to be used in a potentially explosive atmosphere.

Only between November 2016 and October 2017 3348 seismic events were recorded and localized during the reporting time period of 12 months. Most of the seismic events occurred in the monitored area between 2 measurement points and the neighbouring areas. All other monitored areas showed also seismic events but the numbers are lower. The strongest events were recorded near sensor 2 with a magnitude of ML = 2,5 and ML = 2,0. The seismic energy release was highest in June 2017 with 828.096 kJ. The total amount of energy release from November 2017 till October 2018 was 2.799 MJ.

History

A basic seismic monitoring system was installed in 1998 to get information on locations of rock falls or endangered areas. It was established with 8 acceleration sensors in the underground and one 1D seismometer on the surface. The transient recorder from 1998 was a 16bit data logger with a limited capacity of storage and time accuracy. Because of the used sensors (accelerometers have been at that time the only ex-proof sensors) and the aging process of the components the sensitivity of this system was not sufficient and it was decided to update it.

In October 2016 the seismic monitoring system was installed and worked in a test phase and since November 2016 the monitoring system is working with its eight 1D-seismometer stations.

Seismic Network

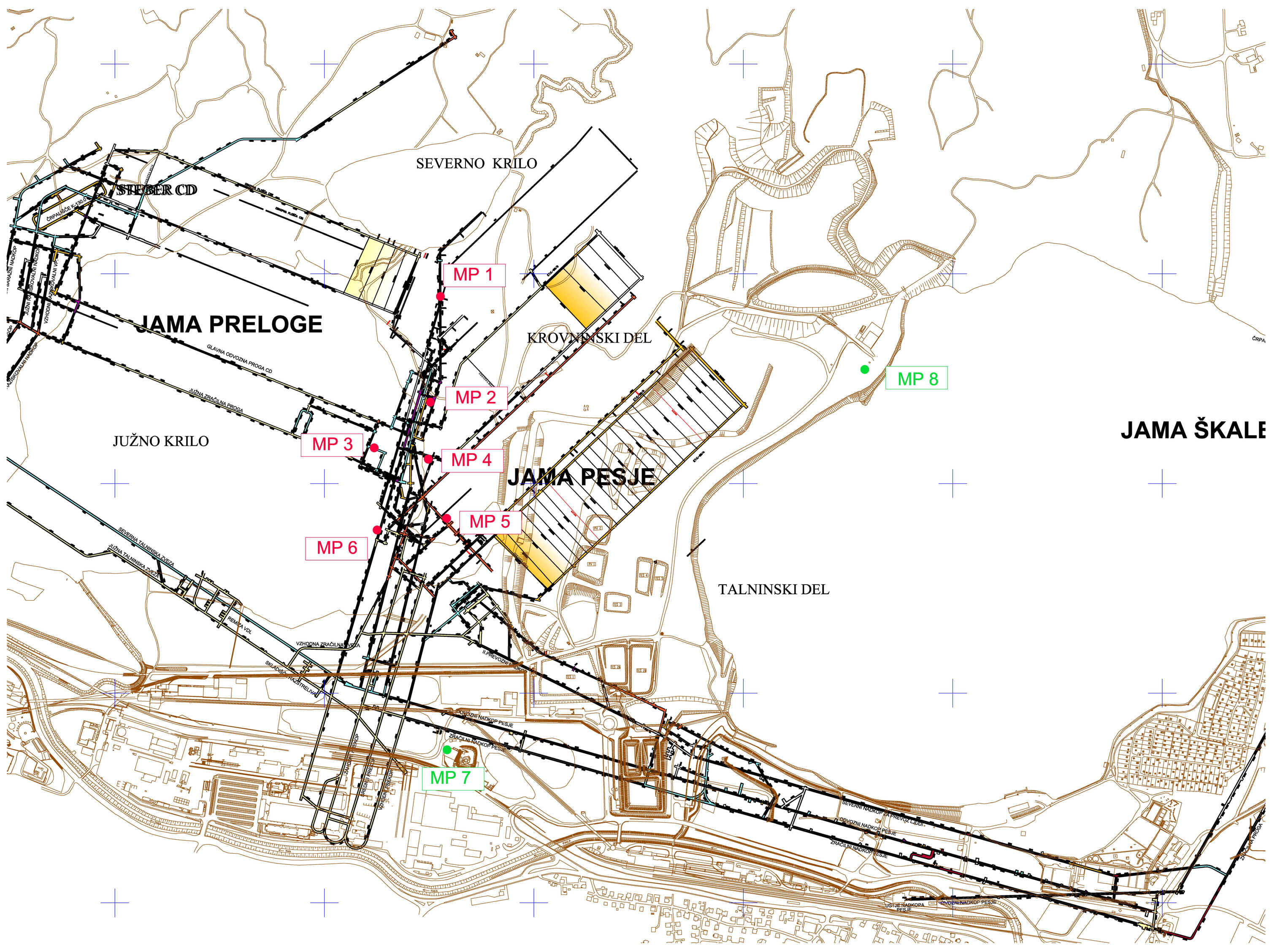

Figure 1: Map of all stations since 2016

The system consists of two seismometers (velocity-proportional sensors) at the ground surface and six seismometers (velocity-proportional sensors) in different cavern fields at a depth of approximately 100 m. The underground sensors are placed in a borehole casing for installation in horizontal boreholes. All sensor-places can be rearranged if necessary. The sensors L-10B/Ex in the mine were produced by the K-UTEC AG and have permission IBEXU15ATEX1131X. So the sensors are allowed to be used in a potentially explosive atmosphere.

For installation in horizontal boreholes special adapted borehole probes are used. Its diameter is 150 mm. An armoured schielded cable leads to the probes and makes it possible to retrieve. With the probe we ensure the mechanical coupling of the sensors. The data of the sensors are transferred by a modulation unit and cables to the central measuring unit.

One digital registration unit (KutecGeoLog data recorders) is installed at the surface in the maintenance building. From all seismometer locations cable ways lead the signals to the data recorder. For data transfer modulation units and demodulation units are used. These components modulate and boost the signals. At the registration unit the signals are demodulated again. The transfer function was determined by a calibration during the installation of the system.

The recorder registers 1h files on a daily basis with a sample rate of 100 Hz. Additionally, if an event occurs a trigger is automatically generated. These triggers have a length of 80 s with a sample rate of 1000 Hz. Each day a staff member of K-UTEC is assessing the new registrations (distinction between e.g. seismic event, blasting, noise) and controls the availability of the system.

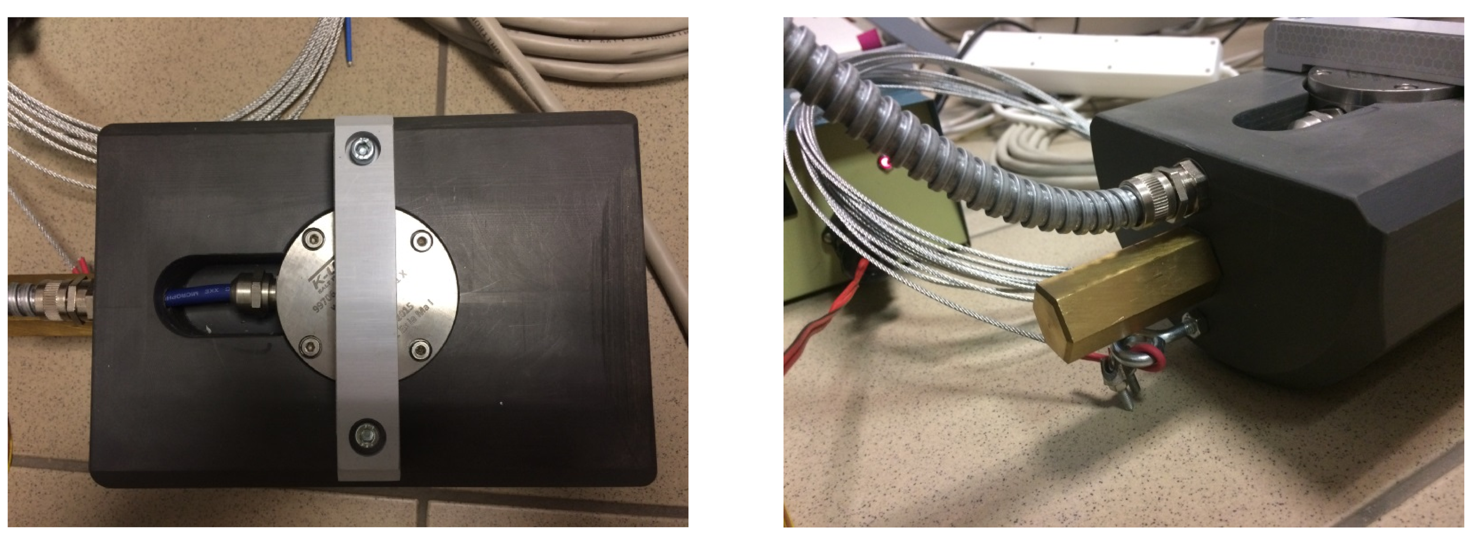

Figure 2: Seismometer L-10B/Ex with borehole probe

First Results

In the first year after the new installation 3348 seismic events were recorded and localized during the reporting time period of 12 months. The localizations of the events are shown in figure 3. Different sizes of the circles are demonstrating different classes of magnitudes of events. The majority of the seismic events occurred in the north and middle area that are circuited by the seismic stations.

The largest number of events occurred in August 2017 with a quantity of 732. Please note that the small number in September and October 2017 is caused by technical problems not by a real decrease of the number of events. The small number of events in December 2016 is caused by the Christmas holidays. When the mining activity is reduced, the number of events decreases significant.

In addition to the location and number of seismic events, the power and the released energy are a criterion for the evaluation of seismic activity. The energy release is calculated from the magnitude of each event using a relation of Gutenberg and Richter. In the first year a huge amount of energy (2.799 MJ) was released. That means enormous stress concerning the geomechanical stability of the mine. About 15% of the annual energy release was caused exclusively by the two strongest events with magnitudes of ML = 2,5 and ML = 2,0 on the 19.07.2017 and 26.07.2017. In June 2017 63 of 504 events were located with a magnitude higher than ML = 1,0 and 387 events with a magnitude higher than ML = 0.

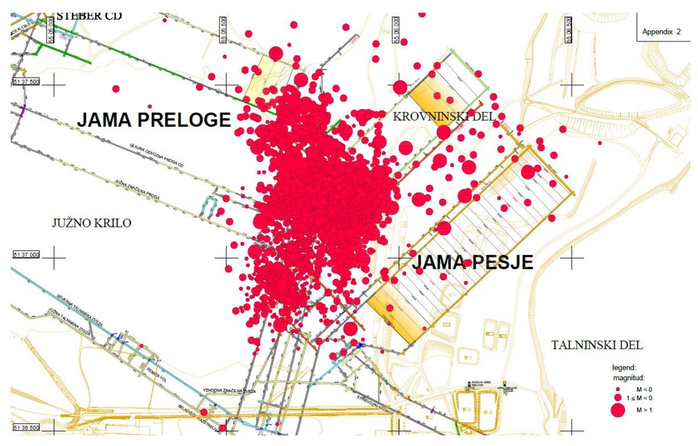

Figure 3: Localisation - Nov 2016 until Oct 2017

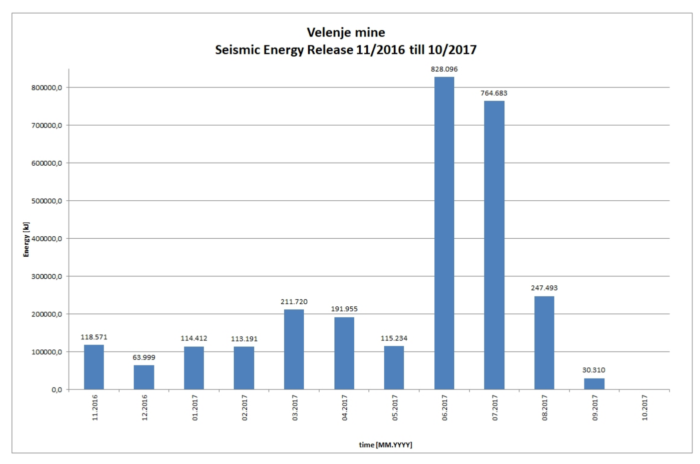

Figure 4: Energy release - Nov 2016 until Oct 2017

	month / year											
	11/16	12/16	01/17	02/17	03/17	04/17	05/17	06/17	07/17	08/17	09/17	10/17	Σ 11/16-10/17
count	198	133	289	147	217	307	347	504	414	732	60	0	3348

Figure 5: event distribution Nov 2016 until Oct 2017

During the last year a significant drop of energy release happened. This is explained by a huge reduction of events and lower magnitudes. Only 219 events occured with a magnitude higher than ML = 0 during the hole year. The number of events dropped from 3348 to 1297. The reduced number of events is a result of systematic preventive measures against rockburst. The seismic system enables us to introduce preventive measures on appropriate places and it became an important part of Velenje mine safety monitoring system.

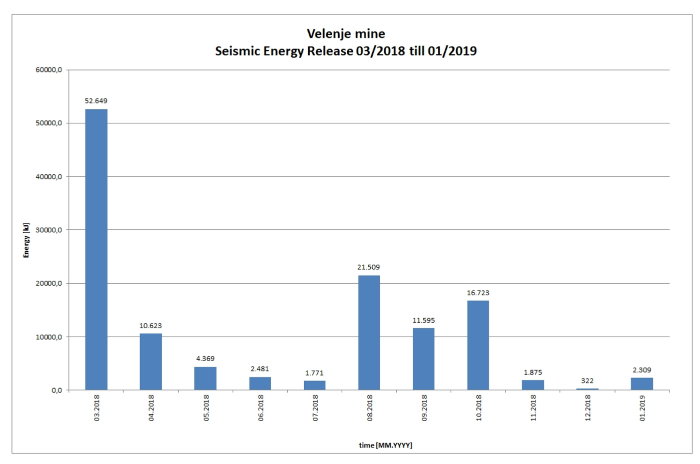

Figure 6: Energy release - Mar 2018 until Jan 2019

	month / year											
	03/18	04/18	05/18	06/18	07/18	08/18	09/18	10/18	11/18	12/18	01/19	Σ 03/18-01/19
count	186	129	63	119	143	116	139	218	73	53	58	1297

Figure 7: event distribution Mar 2018 until Jan 2019

Future Work

Further correlation between the output rate of a lignite respectively stop of work and the energy release should be made to find out some more references.

Due to financial and logistic reasons at the moment it's not possible to install more seismometers in the mine. But for better localisaton it would be highly effective to enclose the monitoring area with more sensors on the surface. Especially northwards measureing point 1 the area is not covered.

References

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