VÁCLAV VAVRYČUK OF THE INSTITUTE OF GEOPHYSICS IN PRAGUE DISCUSSES SIGNIFICANCE AND APPLICATIONS OF MONITORING OF HUMAN-INDUCED MICROSEISMICITY

Microseismic monitoring

IN contrast to large earthquakes known from seismically active regions with magnitudes of six or higher on the Richter scale, microearthquakes are of magnitudes lower than 2.5. They are rarely felt, and are therefore mostly recorded by sensitive sensors only. These microearthquakes usually occur not as isolated events, but in populations of hundreds or thousands of events clustered in time and space in a rock mass. They can be of natural origin or induced by manmade activities.

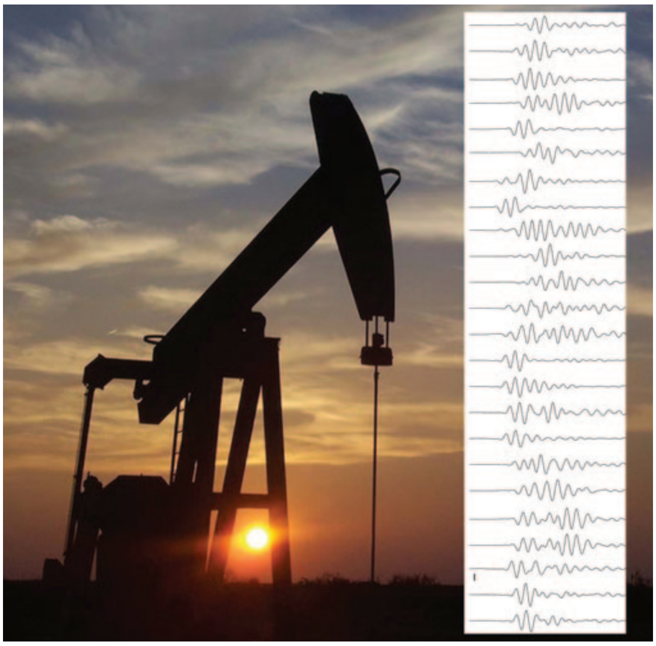
The seismic monitoring of microseismicity exploits advanced scientific methods in combination with high-end technology in order to solve important tasks of social or industrial interest.

Induced microseismicity

Recent seismic observations reveal that microseismicity is often induced by human activities, for example as a result of hydraulic fracturing in oil/gas reservoirs, the excavation of mines or nuclear waste repositories, by building large water reservoirs, by water pumping in geothermal fields or by the sequestration of CO_2 underground.

These activities can impact on the stress in the rock mass, in pore fluid pressure, while also changing volume and load, which can result in sudden shear or tensile failures in the subsurface, usually along pre-existing weakness zones such as microcracks, cracks, fractures or faults.

The seismic waves generated by fracturing are recorded by arrays of three-component seismic sensors, geophones or seismometers, which record ground motion signals with frequencies typically from Hz to tens of kHz.



Oil rig and an example of seismic records for a microearthquake induced in a reservoir

The seismic data is transmitted in real-time to a data centre, collected, stored, filtered and further processed by various methods. Processing this information typically involves the detection of seismic events in noisy traces, the identification of various types of seismic waves, the location of the source, the determination of event magnitude, size and orientation of fracture, and the seismic energy radiated by the source.

Hydraulic fracturing

Microseismic monitoring is useful in some of the most important applications in the oil and gas industries, where it helps to stimulate operations for enhancing reservoir exploitation. To increase production, the rock mass in a reservoir is often exposed to so called 'hydraulic fracturing', whereby a fluid (water mixed with sand and chemicals) is injected into a wellbore to create fractures, which form conduits along which the fluids (such as gas, petroleum, and groundwater) may migrate to the well.

The technique is very common in wells for shale gas, tight gas, tight oil, and coal seam gas, and is a routine industrial operation which induces intensive microseismicity. This microseismicity is connected with creating new cracks and fractures in the reservoir and with their opening and shearing due to pressurised fluid in the rock.

The microseismicity is utilised for mapping the hydrofrac area and consequently for the assessment of the stimulation effectiveness, thereby optimising fracture injection strategies and staging, evaluating fracture barriers, observing fault interactions and assessing the stimulated reservoir volume.

Microseismicity in mines

Microseismicity is also a pervasive phenomenon in mines, where its monitoring is essential for

Oil platform

assessing the seismic hazard and improving the safety in mines. The mining activity considerably disrupts the rock massif by tunnelling shafts, mine corridors, stopes and other excavation volumes which redistribute the tectonic stress and act as stress concentrators.

These enormous changes in stress levels creates new cracks and fractures in the rock, but this can also activate existing natural faults in or close to the mining area and thus produce rock bursts which can cause serious damage or even casualties. The real-time monitoring of the microseismicity in mines can, however, be used for determining the location, time and size of ground instabilities, and therefore in assessing the slope stability in open-pit mines and the pillar and ore pass stability in underground mines, in identifying active fractures and faults, helping in identifying areas of a potential rockburst or roof fall hazard, tracking caving front propagation, minimising downtime, and reducing costs.

Academia-industry collaboration

Since microseismicity is a complex physical phenomenon, its monitoring and analysis requires researchers from universities or academic institutions to collaborate with engineers from companies focused on technology developments and applied seismic research.

In this way, fundamental research provides methods developed in earthquake seismology for studying origins and processes leading to earthquakes, inversions for earthquake source parameters (such as the location, size and type of failure), statistical methods for the analysis of large populations of seismic events, and seismic hazard assessment.

The applied research, on the other hand, is focused on the development and installation of hi-tech seismic sensors forming arrays deployed on the surface or in boreholes; data acquisition systems. This is also focused on the routine processing of data in automatic or semi-automatic regimes which produce catalogues of microseismic events in real-time, their location and magnitude, and the basic statistical parameters evaluating the space-time evolution of seismic activity.

Project AIM

One possible form of collaboration between institutions from fundamental and applied seismic research can be seen in the establishment of a consortium aiming to monitoring and study microseismicity. The feasibility of this scheme was proved by the EU FP7 project 'Advanced Industrial Microseismic Monitoring (AIM)', contract No. 230669, which took place in 2009-2013.

The project promoted synergy between academic institutions from the Czech Republic and Slovakia (the Institute of Geophysics, the Institute of the Rock Structure and Mechanics, and Charles University, all in Prague, and the Geophysical Institute in Bratislava) and industrial partners from Norway (NORSAR Innovation, Kjeller), South Africa (the Institute of Mine Seismology, Stellenbosch), Slovakia (PROGSEIS, Trnava) and Canada (the Engineering Seismology Group in Kingston).

Project AIM focused on microseismicity in the spa area of West Bohemia, in a Norwegian fjord at Åknes produced by sliding of unstable rock slope, in the Little Carpathians, the area close to the nuclear power plant Jaslovské Bohunice in Slovakia, in the Pyhäsalmi ore mine in Finland, in the Moab Khotsong deep gold mine in South Africa, and in the open-pit mines in Cadia-Ridgeway in Australia.

Through the project, the academic partners were able to access high quality datasets collected by industrial partners, and were able to study fracture processes in various geological and tectonic environments and to analyse modes of fracturing and detailed spatio-temporal patterns of microseismicity.

Industrial partners benefited from the project by being able to implement new methods of earthquake seismology to routine data processing, produce more detailed and more accurate microseismic analyses, and enhance their research capacity in microseismic monitoring.

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Dr Václav Vavryčuk
Institute of Geophysics, Prague
Academy of Sciences

phone +420 2671 03111

email vv@ig.cas.cz
browse www.ig.cas.cz/en/aim/aim-home