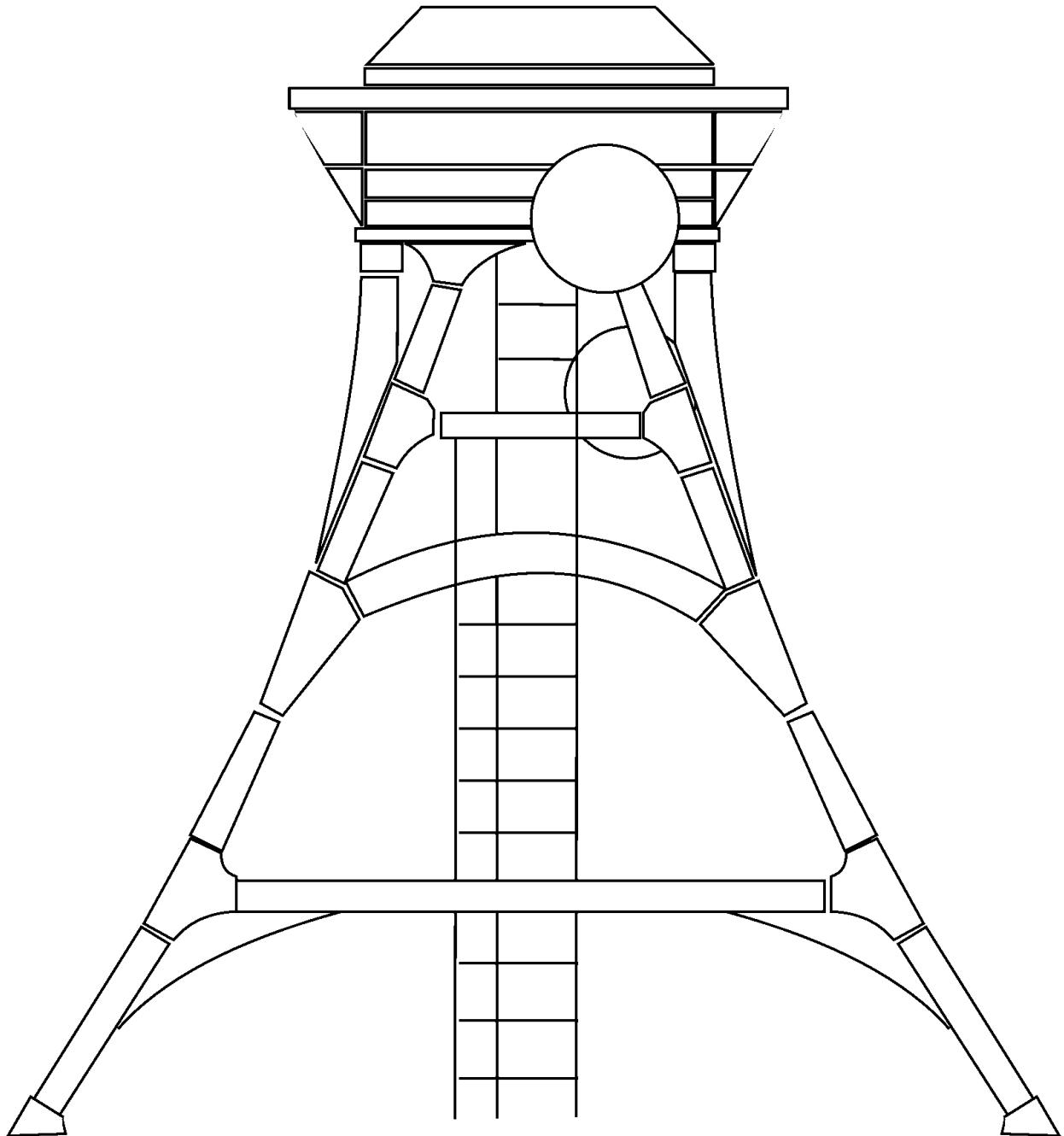




K-UTEC

SALT TECHNOLOGIES



Seismic Monitoring
for Industrial Mining



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Why seismic monitoring:

Seismic events, whether they are caused by local tectonics, fracturing of the overburden or induced by local mining, are only sporadically occurring events, thus the assessment of the general seismicity within an area can only be realised over a longer period of time. These events can occur spontaneously or artificially induced.

K-UTEC has a long time experience within this subject and offers extensive support both in planning and installing seismic monitoring systems but we also offer extensive assistance for the operation of the monitoring system, the interpretation of the single events as well as the general assessment of the seismicity in the target area.

With help of this information it is possible to react to the seismic events. It is also possible to react if the local seismicity increases in a certain area (i.e. refilling of cavities). Mining companies can use these information for enhancing an prove of safety for the public and infrastructure.

The K-UTEC AG Salt Technologies offers

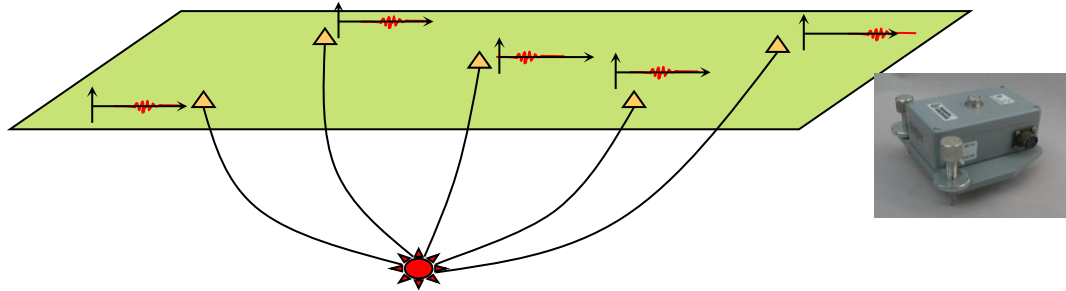
Seismic Monitoring		
<p>➤ establish seismic monitoring systems</p> <ul style="list-style-type: none"> design the best solution for the costumer compute the accuracy of the system in the observed area build up the system in the field 	<p>➤ operate seismic monitoring systems</p> <ul style="list-style-type: none"> daily control of the monitoring system servicing of the system updating of the system, in case of change of the local conditions 	<p>➤ locate seismic events and evaluate the seismic data</p> <ul style="list-style-type: none"> automatic location and alerting manual control of the localization calculation of the event and seismological parameters status report in time intervals as desired by the client

The seismic monitoring systems can be built up on the surface or in mines. The seismometers can be installed on the surface, in boreholes or in the mine.

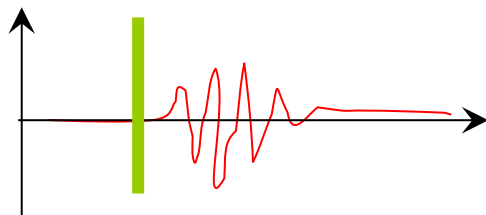
Seismic monitoring system

Design of the monitoring system:

Measurement of the vibration



Arrival time



Event location (x,y,z)
Event time



seismometer



Transient recorder



central computer

Design of a single station (example)



Installation of seismometers and data loggers at the surface and in underground mines

Various types of seismometers

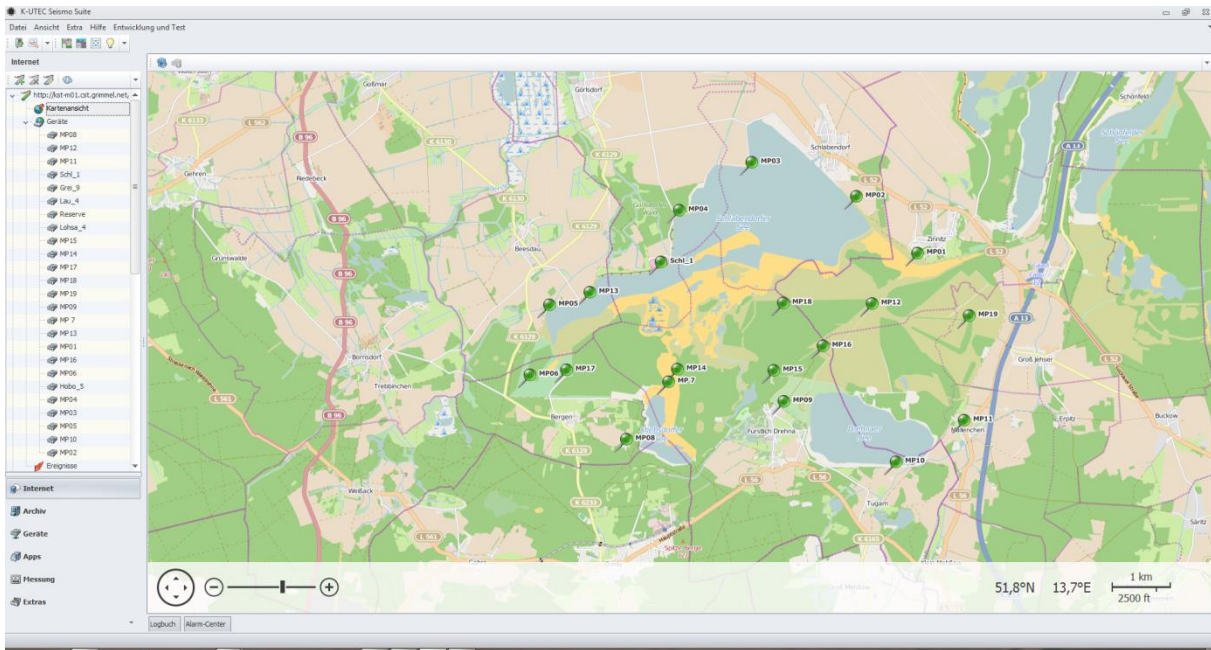
- 3D/1D Seismometers / accelerometers



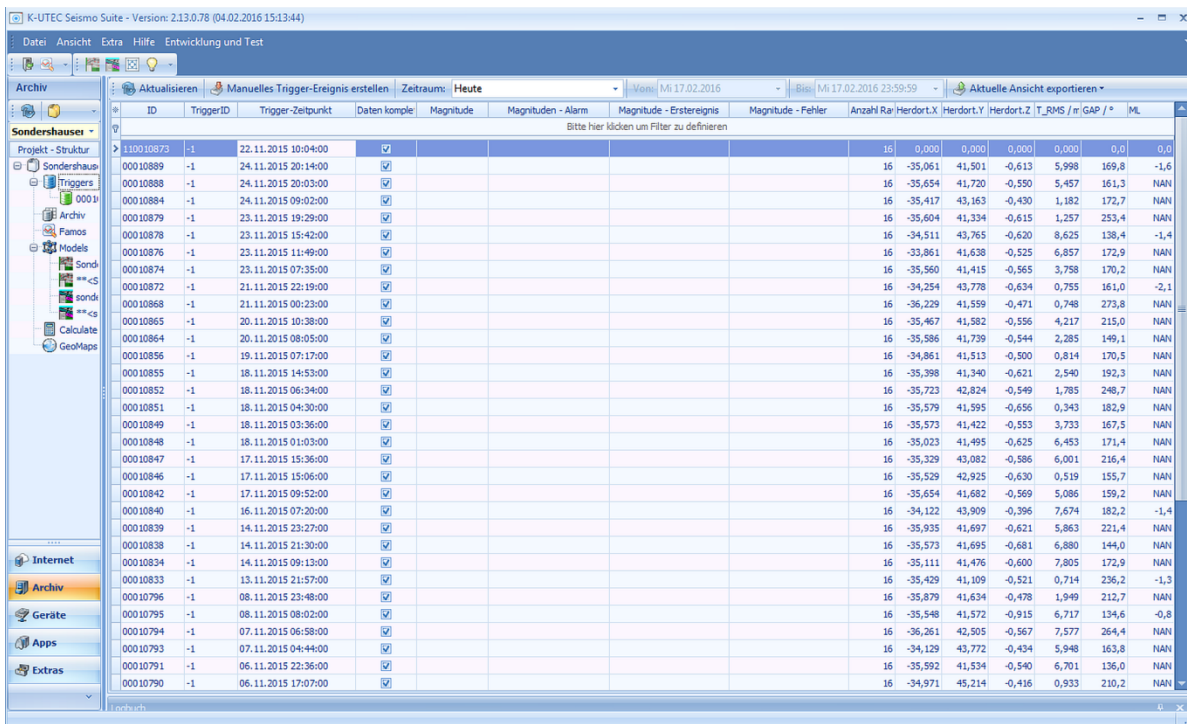
- Accelerators
- Borehole seismometers
- Hydrophones



Signal-processing software:



View of the seismometer stations for monitoring active and not active stations

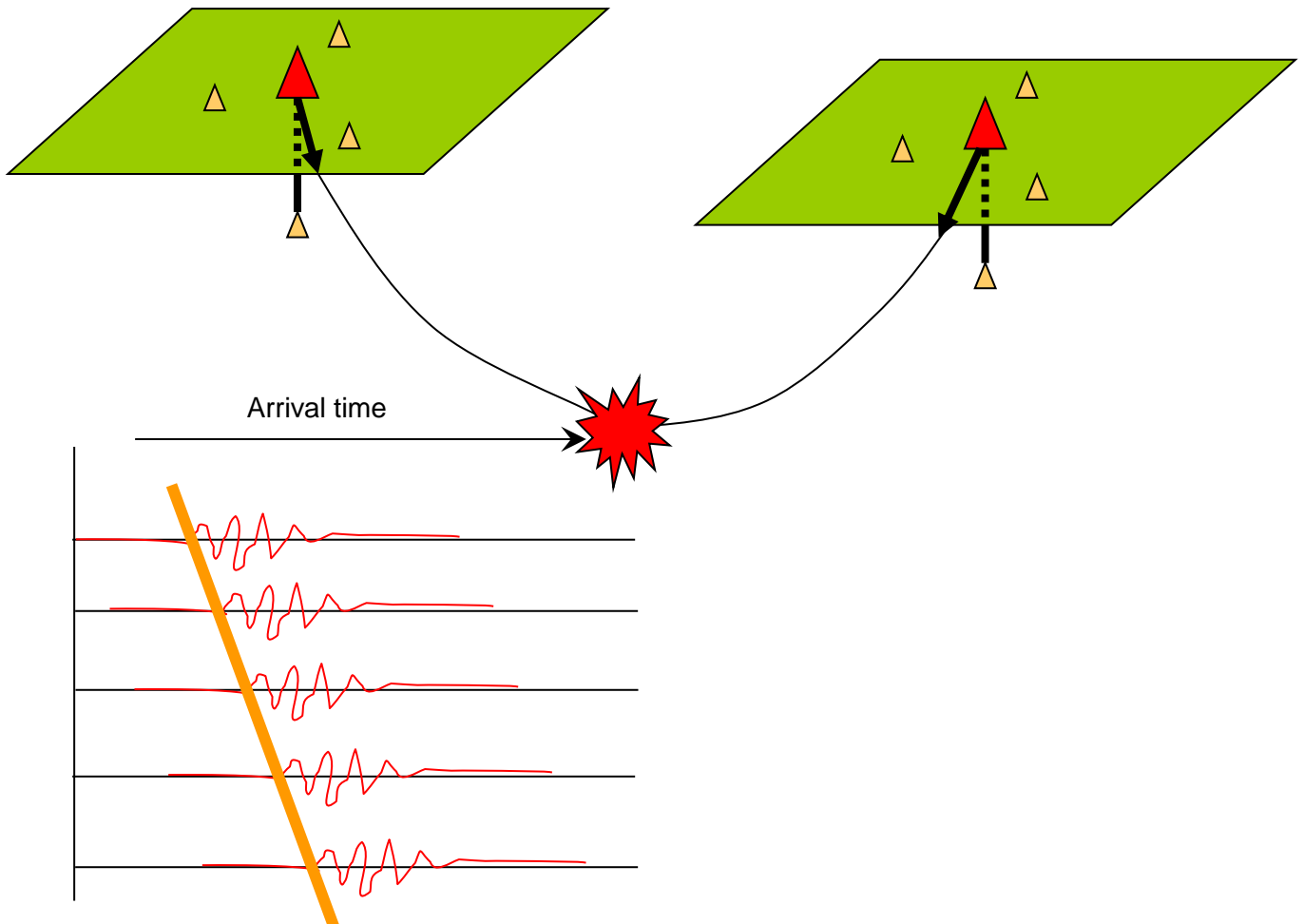
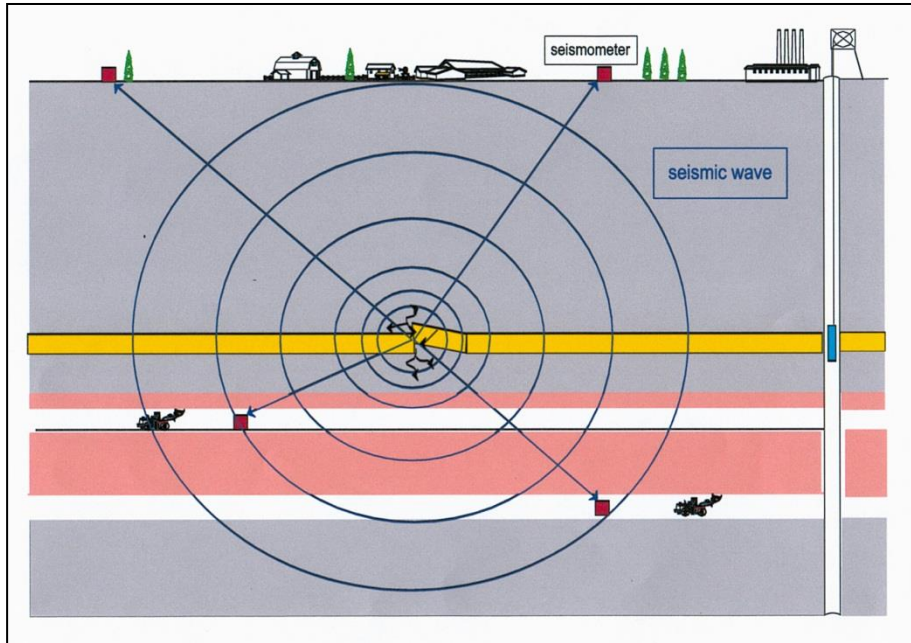


The screenshot shows the 'List of triggered seismic events' in the K-UTEK Seismo Suite software. The interface includes a menu bar, a toolbar, and a sidebar with navigation options like 'Archiv', 'Aktualisieren', and 'Manuelles Trigger-Ereignis erstellen'. The main area displays a table with the following columns: ID, TriggerID, Trigger-Zeitpunkt, Daten komple, Magnitude, Magnituden - Alarm, Magnitude - Erstereignis, Magnitude - Fehler, Anzahl Rai, Herdort.X, Herdort.Y, Herdort.Z, T_RMS / m, GAP / °, and ML. The table contains 20 rows of data, each representing a triggered seismic event with its corresponding coordinates and magnitude.

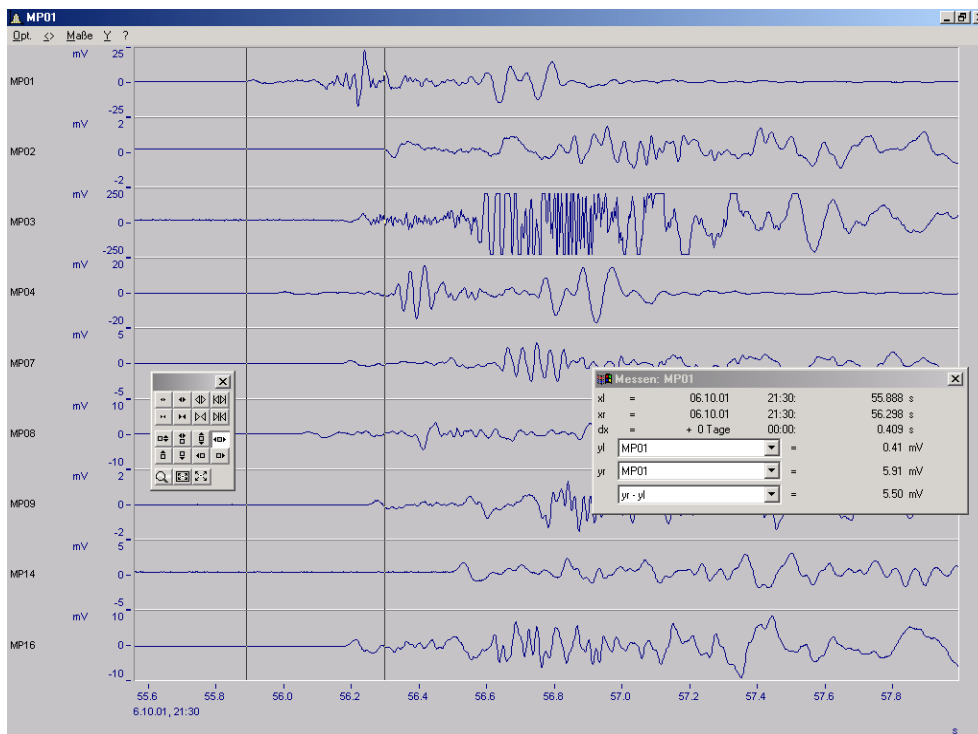
ID	TriggerID	Trigger-Zeitpunkt	Daten komple	Magnitude	Magnituden - Alarm	Magnitude - Erstereignis	Magnitude - Fehler	Anzahl Rai	Herdort.X	Herdort.Y	Herdort.Z	T_RMS / m	GAP / °	ML
110010873	-1	22.11.2015 10:04:00	<input checked="" type="checkbox"/>					16	0,000	0,000	0,000	0,000	0,0	0,0
00010889	-1	24.11.2015 20:14:00	<input checked="" type="checkbox"/>					16	-35,061	41,501	-0,613	5,998	169,8	-1,6
00010888	-1	24.11.2015 20:03:00	<input checked="" type="checkbox"/>					16	-35,654	41,720	-0,550	5,457	161,3	NAN
00010884	-1	24.11.2015 09:02:00	<input checked="" type="checkbox"/>					16	-35,417	43,163	-0,430	1,182	172,7	NAN
00010879	-1	23.11.2015 19:29:00	<input checked="" type="checkbox"/>					16	-35,604	41,334	-0,615	1,257	253,4	NAN
00010878	-1	23.11.2015 15:42:00	<input checked="" type="checkbox"/>					16	-34,511	43,765	-0,620	8,625	138,4	-1,4
00010876	-1	23.11.2015 11:49:00	<input checked="" type="checkbox"/>					16	-33,861	41,638	-0,525	6,857	172,9	NAN
00010874	-1	23.11.2015 07:35:00	<input checked="" type="checkbox"/>					16	-35,560	41,415	-0,565	3,758	170,2	NAN
00010872	-1	21.11.2015 22:19:00	<input checked="" type="checkbox"/>					16	-34,254	43,778	-0,634	0,755	161,0	-2,1
00010868	-1	21.11.2015 00:23:00	<input checked="" type="checkbox"/>					16	-36,229	41,559	-0,471	0,748	273,8	NAN
00010865	-1	20.11.2015 10:38:00	<input checked="" type="checkbox"/>					16	-35,467	41,582	-0,556	4,217	215,0	NAN
00010864	-1	20.11.2015 08:05:00	<input checked="" type="checkbox"/>					16	-35,586	41,739	-0,544	2,285	149,1	NAN
00010856	-1	19.11.2015 07:17:00	<input checked="" type="checkbox"/>					16	-34,861	41,513	-0,500	0,814	170,5	NAN
00010855	-1	18.11.2015 14:53:00	<input checked="" type="checkbox"/>					16	-35,398	41,340	-0,621	2,540	192,3	NAN
00010852	-1	18.11.2015 06:34:00	<input checked="" type="checkbox"/>					16	-35,723	42,824	-0,549	1,785	248,7	NAN
00010851	-1	18.11.2015 04:30:00	<input checked="" type="checkbox"/>					16	-35,579	41,595	-0,656	0,343	182,9	NAN
00010849	-1	18.11.2015 03:36:00	<input checked="" type="checkbox"/>					16	-35,573	41,422	-0,553	3,733	167,5	NAN
00010848	-1	18.11.2015 01:03:00	<input checked="" type="checkbox"/>					16	-35,023	41,495	-0,625	6,453	171,4	NAN
00010847	-1	17.11.2015 15:36:00	<input checked="" type="checkbox"/>					16	-35,329	43,082	-0,586	6,001	216,4	NAN
00010846	-1	17.11.2015 15:06:00	<input checked="" type="checkbox"/>					16	-35,529	42,925	-0,630	0,519	155,7	NAN
00010842	-1	17.11.2015 09:52:00	<input checked="" type="checkbox"/>					16	-35,654	41,682	-0,569	5,086	159,2	NAN
00010840	-1	16.11.2015 07:20:00	<input checked="" type="checkbox"/>					16	-34,122	43,909	-0,396	7,674	182,2	-1,4
00010839	-1	14.11.2015 23:27:00	<input checked="" type="checkbox"/>					16	-35,935	41,697	-0,621	5,863	221,4	NAN
00010838	-1	14.11.2015 21:30:00	<input checked="" type="checkbox"/>					16	-35,573	41,695	-0,681	6,880	144,0	NAN
00010834	-1	14.11.2015 09:13:00	<input checked="" type="checkbox"/>					16	-35,111	41,476	-0,600	7,805	172,9	NAN
00010833	-1	13.11.2015 21:57:00	<input checked="" type="checkbox"/>					16	-35,429	41,109	-0,521	0,714	236,2	-1,3
00010796	-1	08.11.2015 23:48:00	<input checked="" type="checkbox"/>					16	-35,879	41,634	-0,478	1,949	212,7	NAN
00010795	-1	08.11.2015 08:02:00	<input checked="" type="checkbox"/>					16	-35,548	41,572	-0,915	6,717	134,6	-0,8
00010794	-1	07.11.2015 06:58:00	<input checked="" type="checkbox"/>					16	-36,261	42,505	-0,567	7,577	264,4	NAN
00010793	-1	07.11.2015 04:44:00	<input checked="" type="checkbox"/>					16	-34,129	43,772	-0,434	5,948	163,8	NAN
00010791	-1	06.11.2015 22:36:00	<input checked="" type="checkbox"/>					16	-35,592	41,534	-0,540	6,701	136,0	NAN
00010790	-1	06.11.2015 17:07:00	<input checked="" type="checkbox"/>					16	-34,971	45,214	-0,416	0,933	210,2	NAN

List of triggered seismic events

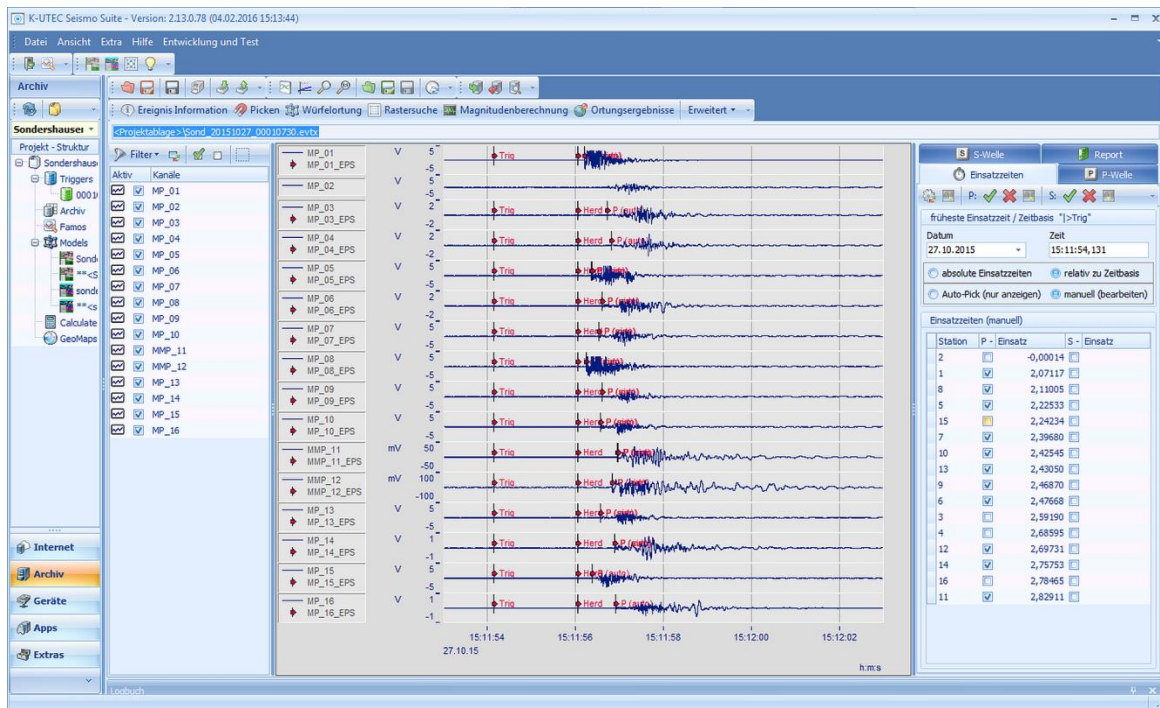
Localization of the events and estimation of the event parameter



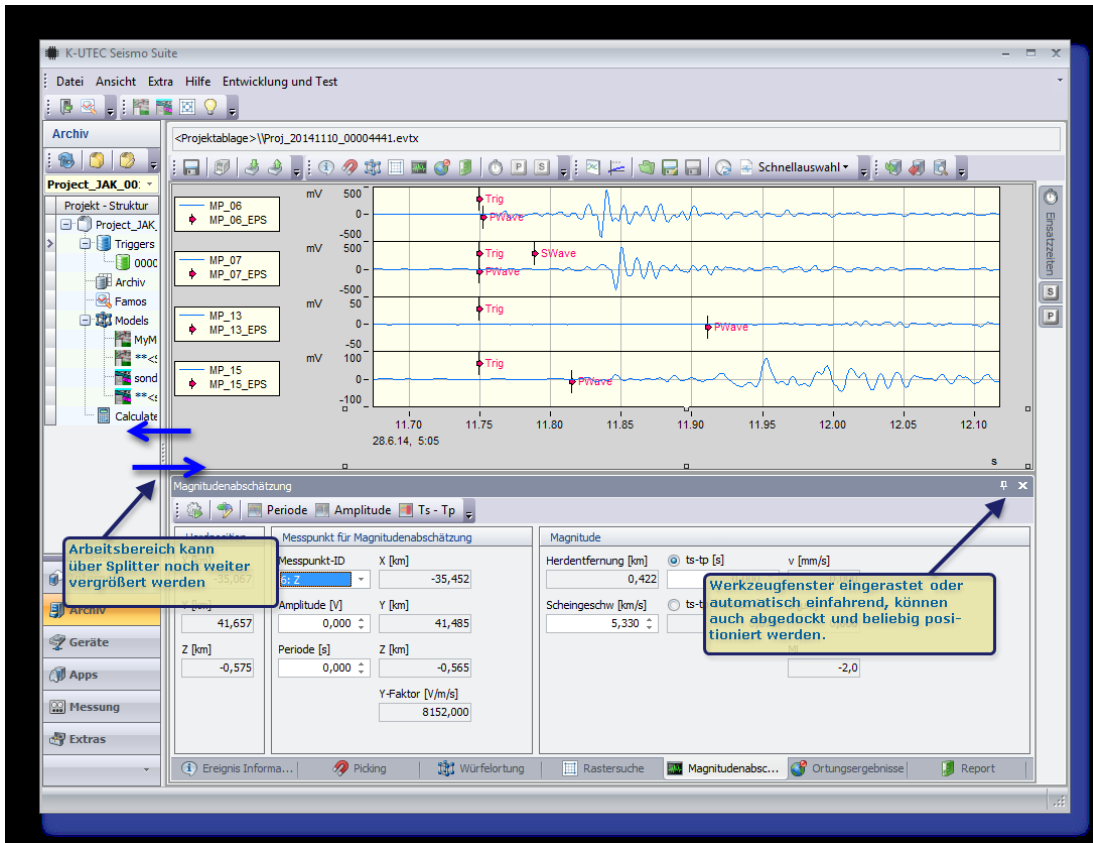
Event example



automatic localization:

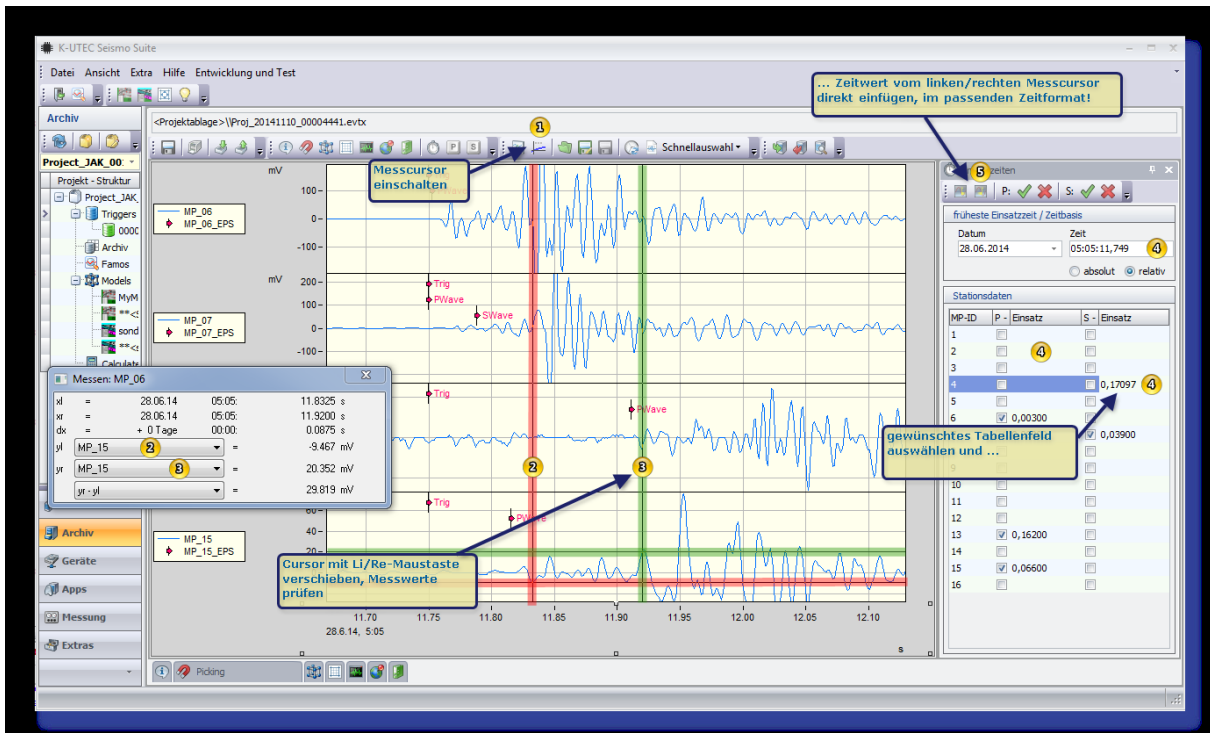


Automatically marked arrival times

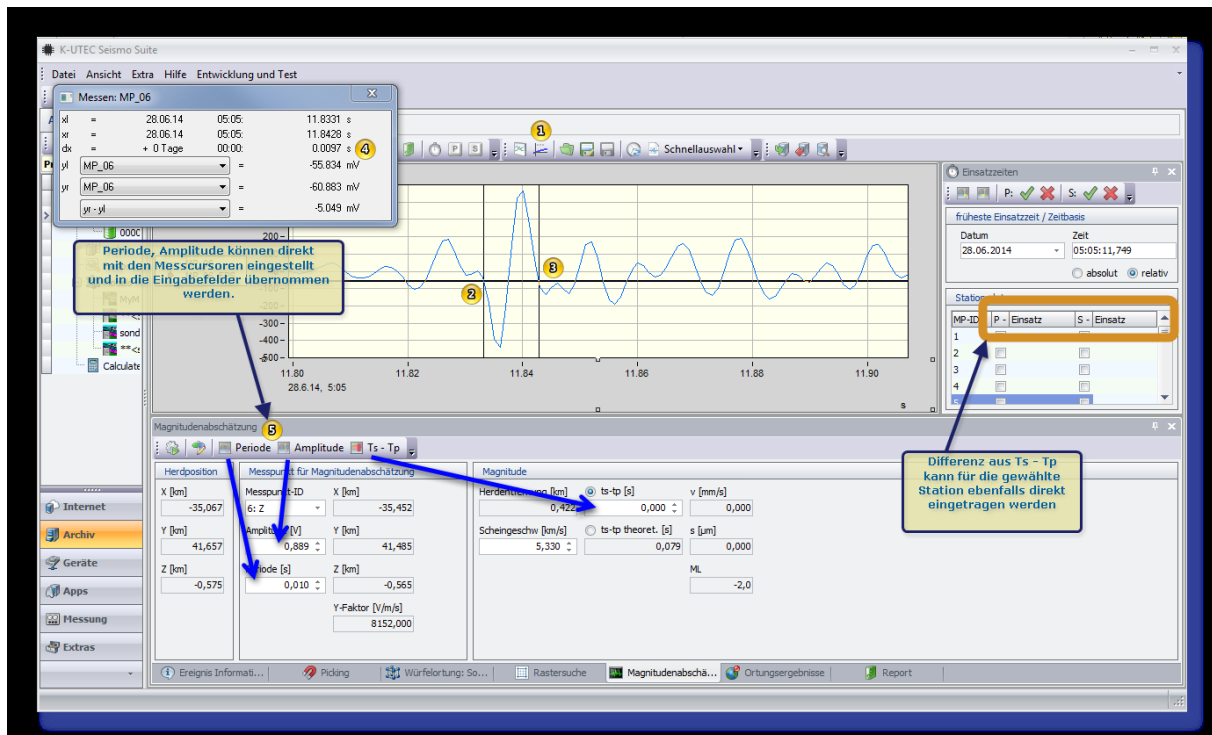


Automatically marked arrival times

manual localization:

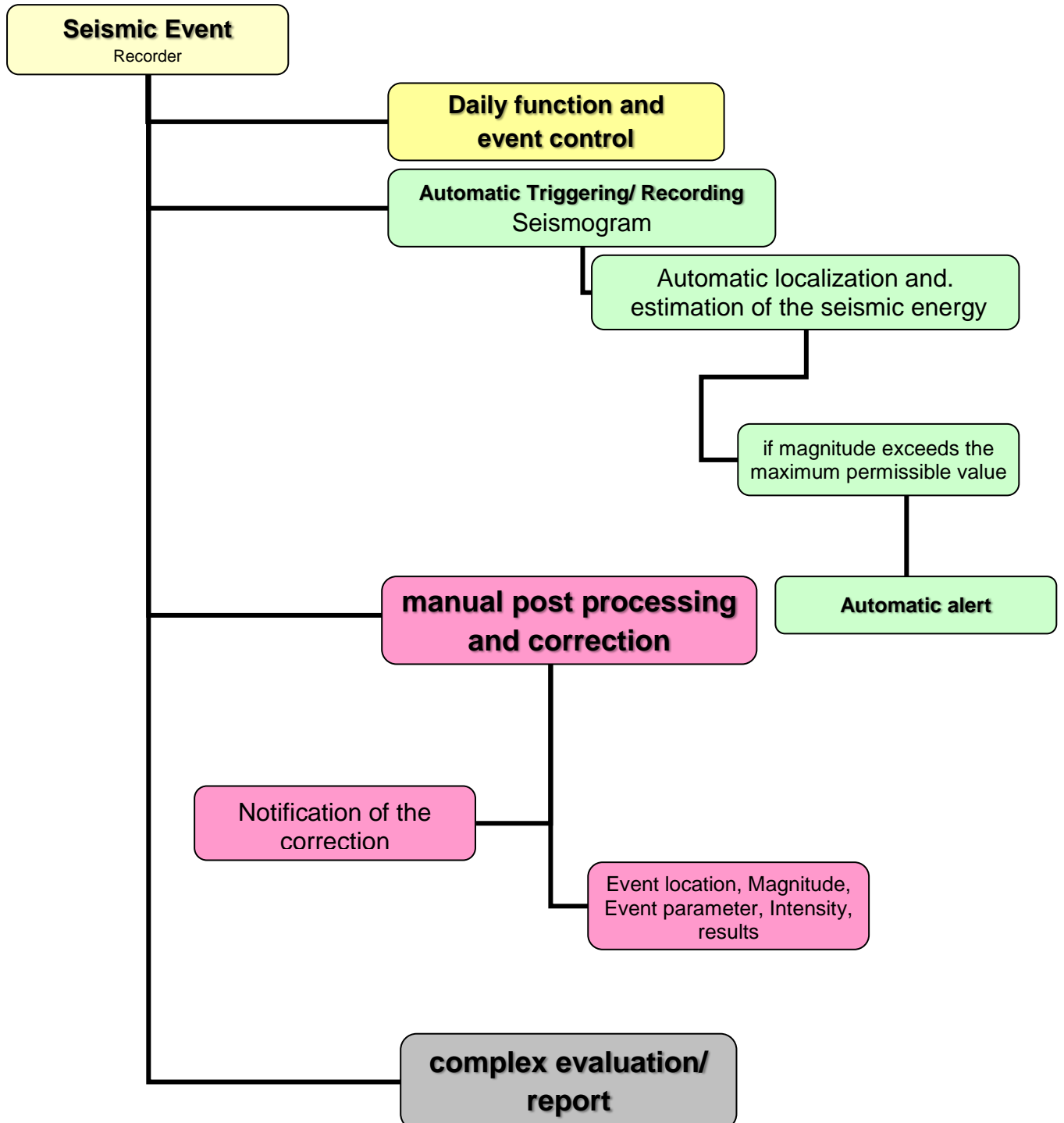


marked arrival times



Localization of the seismic event and calculation/ estimation of magnitude

Scheme of the event processing



Example for event localization over a certain time period in a potash mine (up to 1000 m under the surface)



Technical characteristics of the transient recorder (basic system):

2013 a new concept for seismologic registration unit were carried out by the K-UTEC AG Salt Technologies. This concept was realized until the end of 2013 to the new KutecGeolog. Since December 2013 the first registration units were installed in the field and work since this time in an uninterrupted service mode.

The background of the concept was to develop a device for high resolution data (24 Bit) high sampling rates (5 kHz each channel) time synchronisation (GPS module) and the ability to use modern median for data transfer (internal 4G modem downward compatible, internal LAN port, WLAN hotspot, and more). The power supply is very low with less than 6 W. For this reason it is possible to supply the data recorder by solar power in the field.

The KutecGeolog is able to work together with different sensors like velocity proportional seismometers, accelerators, piezoelectrical pressure transducer and more.



Characteristics:

- Flexible external sensors with different parameters: accelerations, vibration velocities, pressure and more
- Internal mobile LTE modem
- Individual data cloud and Server application
- Up to 64 GByte internal storage, with 24 Bit resolution and 5 kHz sampling rate
- 4 to 8 channels with time synchronized sampling – modular extendable
- Internal mathematical calculation options
- Remote maintenance and remote-software-update with watchdog



The K-UTEC GEOLog is useable for:

- Qualifying of seismic events
- Alerting by specified parameters
- Long-time monitoring of geoscientific parameters
- Mobile and permanent data logging, monitoring and documentation

Miscellaneous

- Temperature range -40° to +70° C
- Compact ALU-Housing 45 mm x 85 mm x 164 mm
- Integrated self-sufficient system monitoring (watchdog)
- Low power input (2,5 W without LTE modem, 6 W with LTE modem)

References of the last years in seismic monitoring by K-UTEC

Project	Location / Client	Size	Year	Remarks
Seismic monitoring of natural and induced seismicity	Teutschenthal, Angersdorf and Salzmünde / GTS mbH, Germany	16 measuring points	Since 1985	Seismic monitoring of the mine deposit, control of natural and induced seismicity, control and guidance of deposit work
installation of a seismic monitoring system	Untereibach/Merkers / K+S, Germany	49 measuring points	Since 1970s	installation of a seismic monitoring system, technical support, consulting
Seismic monitoring of induced and natural seismicity	Bleicherode / NDH-E mbH, Germany	16 measuring points	Since 1994	Seismic monitoring of the mine deposit, control of induced and natural seismicity, control and guidance of deposit work
Seismic monitoring of natural and induced seismicity	Sondershausen / GSES mbH, Germany	12 measuring points	Since 1994	Seismic monitoring of the mine deposit, control of natural and induced seismicity, control and guidance of deposit work
Seismic monitoring of induced and natural seismicity	Bischofferode / LMBV KSE (former GVV mbH), Germany	27 measuring points	Since 1995	Seismic monitoring of induced and natural seismicity, monitoring of non-controlled flood
Seismic monitoring of induced and natural seismicity	Sollstedt / NDH-E mbH, Germany	11 measuring points	Since 1995	Seismic monitoring of the mine deposit, control of mining induced seismicity, control and guidance of deposit work
monitoring of natural seismicity	Zielitz / K+S, Germany	11 measuring points	Since 1997	monitoring of natural seismicity, technical support
Seismic monitoring of natural and induced seismicity during brine process	Staßfurt / LAGB, Germany	16 measuring points	1997 (and before)-2010	Seismic monitoring of natural and induced seismicity during brine process
installation of a seismic monitoring system	Velenje / Premogovnik Velenje, Slovenia	8 measuring points	Since 1998	installation of a seismic monitoring system for a lignite mine
Seismic monitoring of seismic activity	Kirchheilingen / VNG, Germany	1 measuring point	Since 2001	Vibration measurement (monitoring of seismic activity in the area of gas storage caverns)
Seismic monitoring of the former lignite opencast pit Nachterstedt	Nachterstedt / LMBV, Germany	Up to 8 measuring points	Since 2009	Seismic monitoring of the former lignite opencast pit Nachterstedt
Seismic monitoring of controlled flood	Friedenshall, Germany			Seismic monitoring of controlled flood
seismic monitoring of natural and	Kehmstedt / Deusa, Germany			Seismic monitoring of natural and induced



Project	Location / Client	Size	Year	Remarks
induced seismicity during brine process				seismicity during brine process of a cavern field
Seismic monitoring of natural seismicity	Bernburg / esco, Germany	9 measuring points	Since 2000	Seismic monitoring of natural seismicity
Seismic monitoring of induced and natural seismicity	Volkenroda / LMBV KSE (former GVV mbH), Germany	11 measuring points	Since 2002	Seismic monitoring of induced and natural seismicity, monitoring of non-controlled flood
Seismic monitoring of natural seismicity	Salzbergwerk Stetten / Wacker Chemie GmbH, Germany	9 measuring points	since 2002	Seismic monitoring of the mine deposit, control of natural seismicity
Seismic monitoring of natural seismicity	Boulby Mine / ICL, UK	19 measuring points	Since 2009	Seismic monitoring, control of induced and natural seismicity
Seismic monitoring of the explosive compaction activities	Lausitz / LMBV, Germany	4 to 15 measuring points	Since 2012	Seismic monitoring of the explosive compaction activities in several areas in the former lignite opencast pit area
Seismic monitoring of the former lignite opencast pits areas	Lausitz / LMBV, Germany	9 measuring points	Since 2013	Seismic monitoring of the former lignite opencast pits area
Seismic monitoring of a former lignite opencast pit	Schlabendorf / LMBV, Germany	20 measuring points	Since 2014	Seismic monitoring of the former lignite opencast pit Schlabendorf
Seismic monitoring of the vibroflotation soil compaction activities	Nachterstedt / LMBV, Germany	6 measuring points	Since 2015	Seismic monitoring of the vibroflotation soil compaction activities in a former lignite opencast pit area
Seismic monitoring of a cavern field	Hengelo / Akzo Nobel, The Netherlands	10 measuring points	Since 2015	Seismic monitoring of a cavern field
Seismic monitoring of a geothermal plant	Poing /Bayernwerke, Germany	5 measuring sensor stations	Since 2016	Seismic monitoring of a geothermal plant
Seismic monitoring of an underground limestone mine	Auersmacher/Saarstahl, Germany	15 measuring sensor station	Since 2020	Seismic monitoring of an underground limestone mine to monitore sinkhole danger about the mine surface
Seismic monitoring of the geothermal plants in the Munich area	Greater Munich area/Bavaria Germany	prob. 21 sensor stations	Starting 2020	Seismic monitoring of all Bavarian geothermal plants in the greater Munich area/Bavaria