


Geology needs MEMS and Sensors

Dieter Rammlmair

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

GEOZENTRUM HANNOVER

Overview

- **BGR**
- **Research fields**
- **Extreme environments**
- **Examples**
  - Exploration, mining, deposition
  - Environment, early warning
  - Experimental, kinetics
  - Deep sea
  - Nuclear storage
- **Summary and conclusion**

The **Federal Institute for Geosciences and Natural Resources (BGR)** is the central geoscientific authority providing advice to the German Federal Government in all geo-relevant questions.
It is subordinate to the Federal Ministry for Economic Affairs and Energy (BMWi).
In order to secure the supply of mineral resources, BGR provides information in the field of “Mineral Resources” to the industry. For Mineral Economics the developments in the global commodity markets are analyzed and new instruments and concepts for the sustainable use of mineral resources in the scope of Mining Economics and Sustainability are developed.

Organisational Chart of the Federal Institute for Geosciences and Natural Resources

Address: Stilleweg 2, 30655 Hannover
PO Box 510153, 30631 Hannover, Germany
Telephone: 0511 6 43 - 0 or extension
Telefax: 0511 6 43 - 23 04

German Mineral Resources Agency (DERA) / Berlin Office:
Address: Wilhelmstr. 25-30, 13593 Berlin
Telephone: 030 36993 - 0 or extension
Telefax: 030 36993 - 100
Internet: http://www.bgr.bund.de
Email: Poststelle@bgr.de

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President und Professor
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Deputy: Dr. M. Kosinowski 2559

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Deputy: Dr.-Ing. J. Hesser 3736

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Dr.-Ing. T. Lege 3001
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[1] Joint administration of BGR and LBEG in accordance with the administrative agreement concerning the formation of a Geological Survey of the Federal Republic of Germany dated Nov. 17/26, 1958
[2] Permanent post at LBEG
[3] Organisationally appointed to Z.3
[4] Organisationally appointed to Z.8
[5] Organisationally appointed to Z.6
[6] provisional
[7] entrusted with management of affairs

Research fields of BGR

Earthquakes Risk asssement	Marine Ressource exploration	Groundwater
Final Disposal of radioactive waste	Energy ressources	Soil
CCS CO2 storage	Raw Materials	Experiments
Environment	Geomicrobiology	Polar Research

suitable for micro- sensors and MEMS for:

Characterization	Monitoring	Alert systems	Exploration

In the field of Raw Materials Research, BGR investigates and assesses mineral potentials. The focus is upon the analyses of ore deposits of selected, strategically relevant element groups or in selected areas as well as potentials for efficiency improvement in extraction from primary and secondary resources.

One major aspect is the development of fast and interdisciplinary methods at various scales to improve characterization of rock and ore samples as well as mining residues according to their chemistry, mineralogy, texture, resource and contaminant potential, and to develop strategies for exploration, recovery and final long-term environmental friendly deposition of non usable wastes.

Raw Materials

Exploration	multi-sensor grids, active/passive
Ore Deposit	automated core logging, In situ measurement
Mining	equipment based sensor supported smart mining
Mineral treatment	sensor sorting (optical/hyperspectral, physical)
Recovery	multi-sensor drilling equipment, surface scanning
Final deposition	in situ implementation of MEMS, sensors
Monitoring	0D, 1D, 2D, 3D MEMS, multi sensors
Accidents	prediction, threshold

Raw Material Residues

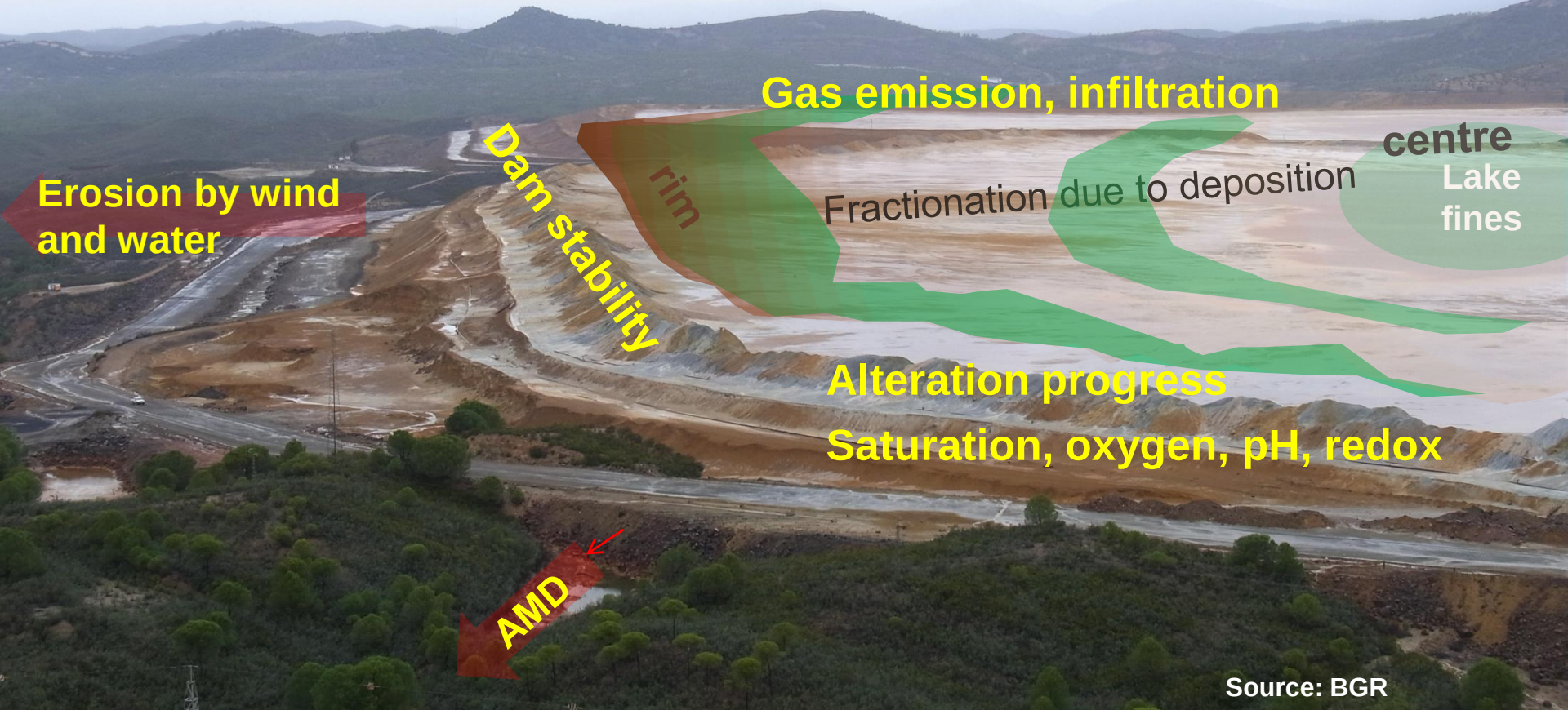
Quantification of the impact of mining residues to the environment

Climatic premisses: radiation, rain, humidity, wind, - direction, T air, T ground,

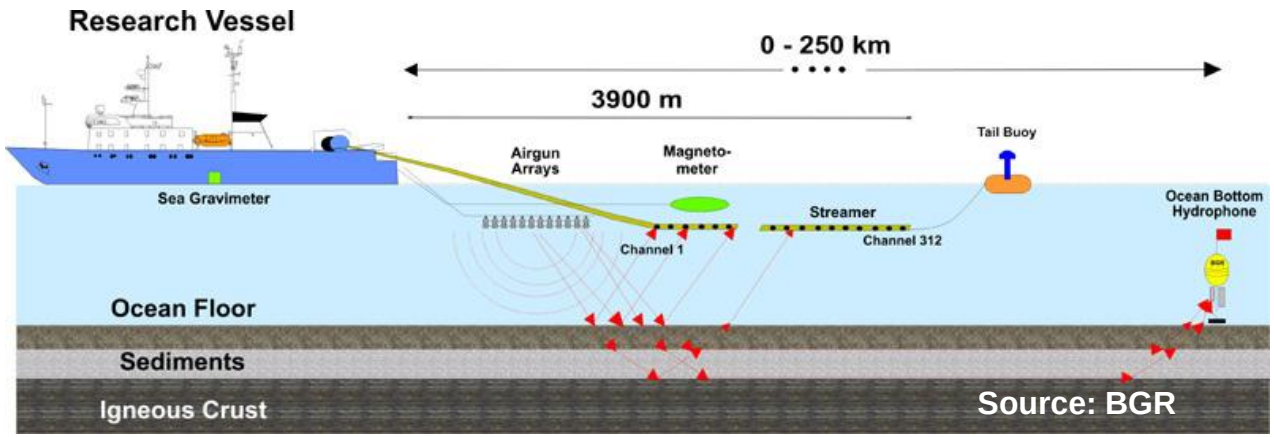
Surface condition: infiltration, evaporation, effluorescence, gas emission, T, erosion

Slope stability: saturation, infiltration, porosity, clogging, reaction, movement

Water quality: AMD, amount, turbidity, chemistry, pH, redox, conductivity



Marine (Geo-)Chemistry



Special requirements:

suitable for seawater and high pressure, eventually for high temperature

Status quo:

Only partially macro-sensors available or in development

Disadvantages of ex-situ analyses

(= sampling and on-board / on-shore laboratory analyses:)

- intricate, time consuming, erroneous, spotlike“

Monitoring of environmental conditions

high temporal and spatial resolution needed for:

- Climate change (gobal ocean circulation, CO_2 storage))
- Deep-sea mining
- Coastal industrial activities
- Research in biogeochemical cycling

Sensor needs:

- Temperature, salinity, oxygen
- pH, CO2, CH4, other gases
- Turbidity, currents
- Nutrients (nitrate, nitrite, phosphate, silica),
- hydrogensulfide
- Dissolved metals, esp. heavy / toxic
- Organic compounds (DOC, TPH, PAH

Geotechnology, final disposal of radioactive waste

The Federal Office for Radiation Protection is responsible for the erection and operation of radioactive waste repositories. The Federal Institute for Geosciences and Natural Resources works on geo-scientific and geotechnical issues in this repository projects, especially the geological exploration of locations, the petrophysical characterisation of the host rock and the analyses of future scenarios for long-term security

Ad hoc and long term in situ monitoring in drillholes: rock type (drill head monitoring), T, pore water characterization, flow mechanism, clogging, fracture generation, deformation, stress, diffusion pH, gas pressure and species, drillhole imaging, chemistry, micro-seismics (ultra-sonic intervals), sealing efficiency.

Geotechnical and geoscientific questions

Parameters:

Concentrations of CO_2, CH_4, O_2, N_2, Ar, He, SO_2, H_2S, Rn in gas and fluid
Isotope ratios $\delta^{13}C$, $^3He/^4He$; α-, β-, γ- radiation,
pH, pe, conductivity, density, chemistry of fluids, P, T, humidity
Gas and fluid flow
GW-level, current velocity and direction
Climate, insolation, IR-radiation
Ground stress/pressure, deformation and tilt
Heat capacity and t und thermal conductivity
Electrical potenzial measurement

Environment:

Laboratory, bedrock laboratory, soil, aquifer, sea water, highly saline formation water

Geotechnical and geoscientific field

Application modes:

- **Stationary arrays** for time series multi parameter sensors with remote data transfer e.g. drillholes monitoring, long term maintenance-free for GW monitoring in deep drillholes
- **Mobile arrays** for mapping spatial changes in unmanned aerial vehicles, ground vehicles, autonomous or remote controlled submarine equipment, in slim and robust driving core probes for soil mapping (1m)
- **Inexpensive, spatially gettable sensors** with GPS and remote data transfer and lifet ime ≥ 1 year for installation on land, on water body beds, in floating bodies (CO_2). Recoverable, environmental friendly or biologically degradable?

Geotechnical and geoscientific field

Technical applicability

- Robust sensors for slim driving probes for autonomous time series records for CO2 in fluid / soil gas in soil and sandy aquifers
- Energy sources for data acquisition and transfer.
- Possibilities for data storage and transfer in the ocean, in soil, underground, deep drillholes. Transfer rates, - distance, repetition.
- Mobile micro laboratories for gas, isotope, water analyses (chemistry, molecules)for remote controlled vehicles and autonomous vehicles
- Sensitivity, drift, comparability, reproducebility, calibration of sensors
- High resolution, wide range, sensitivity for electrical tension, voltage peaks, human potentials, lightening in the field, P, T, pH, radioactivity, dirt proof, lifetime, aging
- Contact in drillholes for geomechanical measurements

Equipment for extreme environments

(T, P, pH, redox, chemical, lifetime, erosion, corrosion, shock etc.)

Hazard	Prediction of floods, tsunamis, glacial lake and dam failure, earthquakes, volcanic eruptions, lahar landslides, avalanges, collaps
Water	Quality, quantity, reservoir, saltwater transgression, contamination, ground water generation,
Microbiology	Sterile, activity, genom, efficiency, inhibition
Soil	Structure, transport, quality, needs
Mineral/Ore	Exploration, characterisation, mineral treatment, smart mining, exploration
Rock	Deformation experiment, drilling, cutting, smart mining, safety
Contaminant	Hydrocarbons and derivatives, nuclear, industry, drilling, fracking, mining, leakage

Summary and conclusion

Micro sensors and **MEMS** play an increasing role in geology as „low cost“ facilities for identification and separation, for 1D, 2D, 3D multiscale, multiparameter monitoring and early warning, and require long term stability at chemically, physically extreme sites:

- **Natural systems**: environment (marin, terrestrial), climate, water, avalanges, lakes, floods, tsunami,earthquakes, volcanoes, sea level changes, erosion, vertical and lateral displacement
- **Anthropogenic deposits**: raw materials and related products, mines, dams, gas pipelines, leaks, AMD, nuclear deposits,
- **Technical systems:** analytical instrumentation, experiment under extreme conditions, smart mining, mineral treatment
- **Exploration:** minerals, HC, water, thermal energy, CCS, nuclear deposits, drilling, status of alteration
- **Raw materials:** terrestrial, marine, smart mining, mineral treatment, deposit