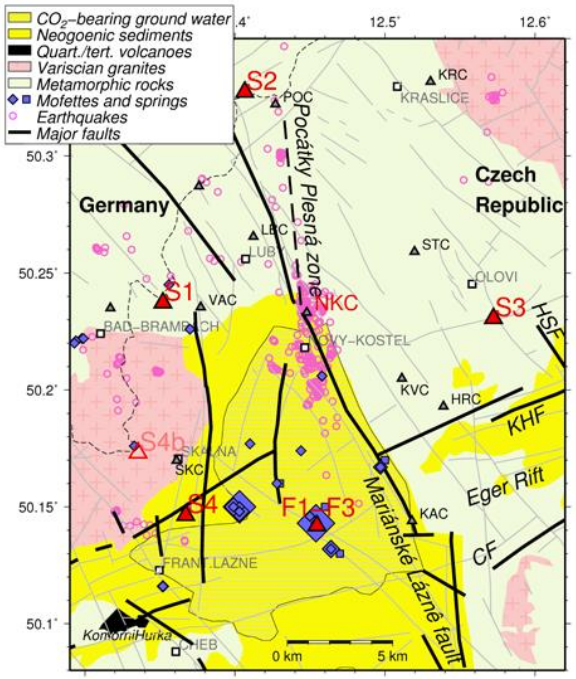
LABORATORY IN SITU – FIVE SHALLOW BOREHOLES

The area is a unique site worldwide for an interdisciplinary drilling program advancing the field of interactions among earthquakes, fluids, rocks, and biosphere. A modern, comprehensive laboratory at depth will study three interconnected areas of primary research: earthquake swarms, fluid flow through the crust and mantle-derived CO_2 and He degassing, and the composition and processes of the deep biosphere. Specifically, such a laboratory will comprise a set of five shallow boreholes some of them with 3D seismic array. The laboratory will be established under the International Continental Drilling Program (ICDP) to have unique multi-parameter observation of earthquake swarms and related phenomena.



Drilling sites. S1-S4 mainly seismological monitoring; F1-F3 fluid and biosphere monitoring. Existing seismic stations at surface are marked by grey-filled triangles.

MONITORING SITES

The monitoring depth of shallow boreholes will be a few hundred meters, which will improve the earthquake and fluid recordings. It will offer the possibility to study extremely small-magnitude earthquakes and analyse the fluid-induced source processes. So far, irregular fluid probing and analysis has been performed at the surface only, often in irregular regime. The located and well-studied sites of massive CO_2 degassing offer the possibility for building a new generation of continuous real-time fluid monitoring in safe and logistically accessible areas.

Fluid monitoring at different depths will separate the effects of surface and deep processes related to composition and rate of fluids. Regular and persistent occurrence of the earthquakes in this region helps in designing monitoring network for optimized analysis.

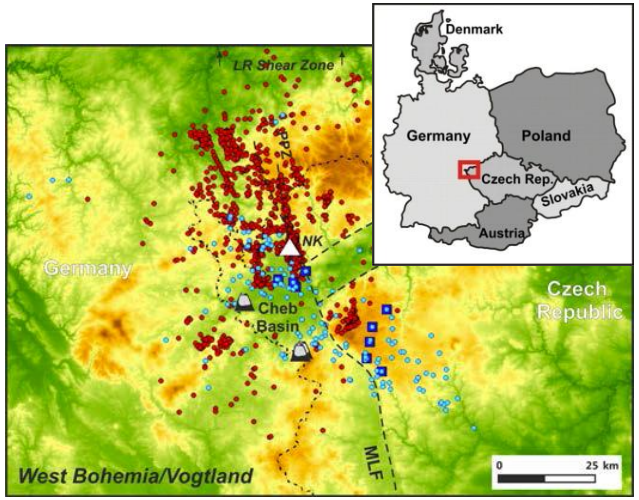
FLUIDS AND DEEP BIOSPHERE

Carbon dioxide degassing in the Cheb Basin in form of dry mofettes is the most prominent in the national natural reserve Soos, Bublák near village Vackovec, or Hartoušov. These places can also be investigated for CO_2 interactions with biosphere.

Microbial ecosystems abundant in the subsurface may react to changes in composition of fluids. Thus, the long-term degassing of mineral-rich waters and gases in granitic and sedimentary layers makes this area ideally suited to study the effect of CO_2 on the deep biosphere and the development of life at depth.

EGER LABORATORY TO STUDY EARTHQUAKES, FLUIDS AND DEEP BIOSPHERE

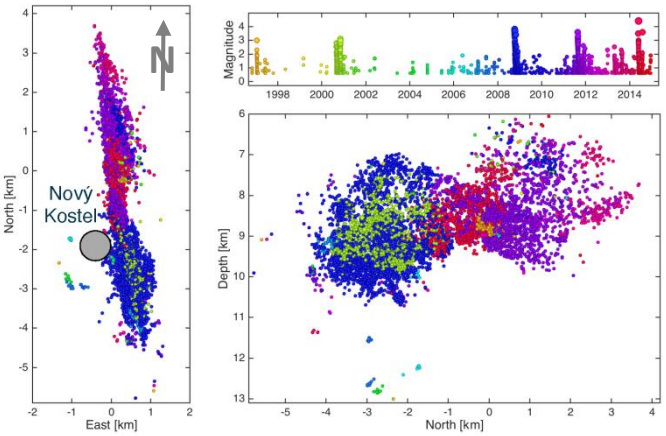
The westernmost part of the Czech Republic and adjacent area in Germany is known for the geodynamic activity represented by earthquake swarms and large-scale degassing of CO_2 fluids. The region is also characterized by numerous mineral springs, Tertiary/Quaternary volcanism and neotectonic crustal movements, located at the intersection of two major intraplate fault zones, the Eger Rift and the Mariánské Lázně Fault. It is likely that all these phenomena are related to a common origin. Geodynamic activity, fluids and earthquake swarms represent a unique phenomenon worldwide. Currently, it is well accepted that many earthquake swarms are driven by fluids in the crust. However, it is still unknown how fluids are driving the persistent earthquake activity. Long-term monitoring is essential to understand these phenomena and their interactions. It can contribute to answer these questions.



Epicentres of earthquakes from 1991-2015 marked by red circles. Blue circles and violet squares represent CO_2 emanations at surface and mofettes. Triangle marks the Nový Kostel NK focal zone. Quaternary volcanoes are indicated.

EARTHQUAKES SWARMS

Earthquake swarms represent an intensive, long lasting, low magnitude seismicity that contrasts with more typical shock-aftershock sequences. Such seismicity can be felt by the population, sometimes with damages of buildings. They are nowadays recognized in many regions worldwide under different tectonic settings, mainly in volcanic and geothermal fields or at margins of tectonic plates. They can also represent intraplate activity as is the case of the West Bohemian region. However, their mechanism is still not fully disclosed. They can occur as precursors of larger earthquakes as, e.g., during recent L'Aquila 2009 earthquake in Italy. In West Bohemia, at present, the highest concentration of earthquake activity and CO_2 degassing occurs in the area of the Cheb Basin, near three Quaternary volcanoes and at the intersection of major tectonic lines. It seems that the earthquake swarms are related to the re-activation of a complex system of faults, at least for the Nový Kostel area.

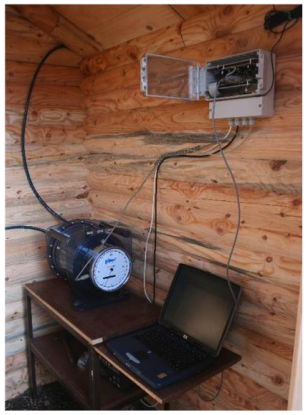


Seismic activity in the Nový Kostel swarm area with the majority of earthquakes, which dominated the activity during 1997 – 2014. Left: map of earthquake epicentres demonstrating that the foci of events align along steeply dipping fault. Right bottom: vertical cross-section with hypocentres along the fault. Right top: occurrence of the earthquakes with time, vertical axis shows Richter magnitude of individual events. Seismic activity is colour coded according to time of occurrence.

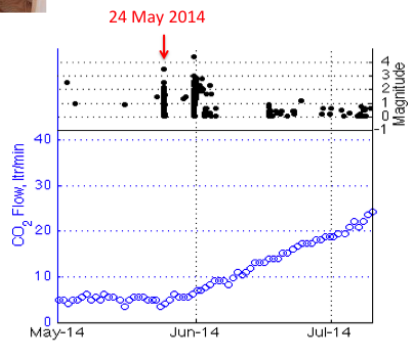
FLUIDS AND EARTHQUAKES

CO_2 degassing is concentrated in the Cheb Basin and surrounding areas in the form of dry mofettes and mineral springs. High portions of mantle derived helium and CO_2 indicate magmatic origin and fluid transport from the Earth's mantle. On their way to the surface the fluids penetrate through faults and are related to the earthquake activity.

Monitoring of the ascending CO_2 and groundwater level shows that the rate and isotopic composition varies with time and is related to the stress accumulated in rocks. This is influenced by changes in tectonic stress field and fluid pore pressure reactivating system of faults and dislocation on them.

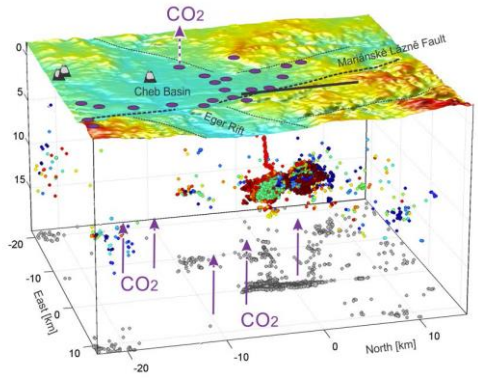


Present monitoring of CO_2 is not explicite, because fluids and seismic activity show different trends for different periods. The most peculiar anomaly was found in 2014 when steady massive increase of dry CO_2 flow was detected in Hartoušov mofette, which coincided with the beginning of the seismic activity in the Nový Kostel area.



Flow of dry CO_2 in the Hartoušov borehole and earthquakes prior and during the 2014 seismic activity in Nový Kostel focal zone

LABORATORY IN SITU – LONG-TERM MONITORING



3D view of the earthquake zone. Colour of earthquakes represent progress in time (with grey circles as their bottom projection). Violet arrows sketch possible CO_2 migration paths, violet ellipses indicate occurrence at surface.

Open questions

- What are the physical and chemical processes leading to earthquake activity and fluid mobility?
- What are the pathways of fluids through the crust and how are they influenced by tectonic stress variations?
- How many geological processes influence the deep biosphere and the early evolution of early life at depth?

Getting answers

- Develop a modern, comprehensive laboratory in situ with high detection capability
- Study earthquake swarms, CO_2 degassing and deep biosphere and their interactions
- Understand fluid and magma migration, and fluid-rock interactions through the crust
- Map structural heterogeneities in the swarm region

IG ASCR

The project involves scientists from Germany, the Czech Republic, United Kingdom and the USA.

Contact: T. Dahm, T. Fischer

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